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American Steel Castings

A high tribute was paid by Dr. C. J. Dadswell in a Paper which he presented to the Bradford Conference of the Institute of British Foundrymen to the progress made by the American steel foundries. He had just prior to the Conference made an extensive tour of the industrial centres of the United States. It is impossible for the student not to have noted that recent American contributions to the literature of the subject of steel castings have been of a particularly high-grade order. Moreover, there is a background of confidence that steel founders in that country are working on sound principles. The theoretical work of Herty, Briggs, Gezelius, Batty and others has been applied to practice with both enthusiasm and success. A typical instance of such work is a Paper by J. A. Duma and S. W. Brinson, of the Norfolk Navy Yard, Portsmouth, Va., on "The Application of Directional Solidification to Large Steel Castings." Amongst the many pointers detailed in this Paper, none is more important than the advocacy of the use of small models for ascertaining the best methods for the making of the pattern, the core boxes and the mould. Under American conditions the costs of preparing a model are in the nature of 2 per cent. of the total founding cost of a casting.

A statement which is worthy of wide dissemination and appreciation in steel-foundry circles is that "mould relieving is to a casting's solid contraction what directional solidification is to its fluid contraction." The authors point out in this connection that solid contraction involves both the inherent hot-shortness of the steel and the deformability of the mould. For a casting to tear two conditions are necessary—a high temperature, ranging between 1,260 and 1,400 deg. C., and high impeded contraction stresses of the order of 800 to 2,500 lbs. per sq. in. Of the two, the latter is controllable and consequently avoidable. Thus steps are taken to use mould materials which are readily collapsible immediately after pouring. Obviously the sand itself can give rise to defects in the castings, and blows, pinholes and gas cavities are said to be minimised by using materials carrying a low moisture content, a high permeability and a complete absence of organic matter. In the Norfolk Dockyard reliance is placed on synthetically-bonded sand mixes consisting of washed silica sand, water and bentonite. During the preparation of the metal by the basic electric process full cognisance is taken of the deleterious effects of non-metallic inclusions and the ameliorative effect of alloying and heat-treatment. On a 0.25 per cent. carbon low-alloyed steel the average elongation and reduction of area figures are 30 and 50 per cent. respectively, associated with 31 to 33 tons tensile.

In establishing controlled directional solidification to castings, it is often of great practical difficulty to institute for any given casting a favourable temperature gradient by orthodox methods, and the authors suggest that by having recourse to one or more of the following methods success may be attained. The methods listed fall into eight categories:—(1) Banking or partial reversal—20 to 45 deg.; (2) top-pouring of risers; (3) heading; (4) gating—parting, multiple, and stepwise; (5) chilling, coring and design; (6) padding—outside, inside, eccentric; (7) sectioning or partitioning of castings; and (8) preheating the cope.

To illustrate the application of the above precepts, a number of practical examples are given, but to our mind the most important factor of all is recording of the data essential to the production. In the case of anchor shanks and crowns, data are listed under the four main headings of mould materials, steel data, founding and heat-treatment, and apparently this system is followed for all castings of major importance. Under the heading of "Mould Materials," the nature of the sand used for facing (both cope and drag, which may be different), backing, internal and external cores, are specified by numbers referring to standardised mixes. The information recorded as "Steel Data" includes the compositional specification adhered to, the pouring temperature, the size of the ladle nozzle to be used, the pouring time in seconds, excluding the riser, and the rate of the rise of the metal in the moulds in inches per second. "Founding," the third heading, sets out information of the most valuable character and shows the banking angle of the mould, the temperature gradient obtained, the sizes of the feeding head, ingate and risers, and the weights of the casting and the casting plus the risers and gate. The temperature gradient obtained in connection with anchor shanks was measured by immersing thermocouples into the metal to a depth of 1 in. in the bottommost and topmost positions of the shank. Heating up, holding and cooling times and the annealing temperature are detailed under the heading of "Heat-treatment."

It will be conceded that whilst there are still a number of variables yet to be controlled, the scheme outlined is such that the ascertainment of the cause of a waster will be relatively easy to diagnose and cure. In this connection the authors plead for more quantity information regarding the amount of padding and the size of external and internal chills.

(*Continued on page* 134.)

Problems for Copper Producers

BY "ONLOOKER."

Although the domestic copper price in the United States has recently displayed a slightly firmer tendency to the extent that custom smelters and secondhands have advanced their selling limit to 11 cents, thus coming into line with the primary producers, who after a gallant struggle to maintain 11¼ cents reduced to 11 cents a few weeks ago, the outlook is not particularly encouraging for those who have copper to sell. The root of the price weakness lies in the fact that while demand on the American home market is moderately good, export business has dwindled to small proportions, and there are no indications that a revival lies ahead in the near or distant future.

That is fairly obvious from the state of affairs in Europe, but what is perhaps not quite so clear is the fact that there is a very large production in South America, almost entirely from mines owned by the great U.S. companies, which is shut out from the United States on account of the 4 cent import duty and which normally found its way to foreign markets. These South American mines possess very large reserves of ore, and are among the cheapest producers in the world.

With the price in New York at 11 cents this copper from Chile and Peru could probably be shipped at a profit, even though it would be subject to the import duty of 4 cents per pound on entering the U.S.A., but the margin would not amount to much, and the pressure of these additional supplies might well depress the domestic price below 11 cents. There is, of course, nothing to prevent foreign copper from entering the States provided that the duty is met, but a more likely course would be for the South American product to be shipped for lodgement in bonded warehouses for upwards of three years without the necessity of paying the import tax.

An Alternative Scheme

It may be argued that this is only postponing the unpleasant impost, but much can happen in three years, and it is always open to the owner of the copper to re-ship for another destination. Out of this arises another possibility and one which is already being taken advantage of by those who have overseas connections. That is the fabrication of manufactured goods from the bonded metal for sale in a foreign market, and the plan undoubtedly has much to recommend it. It is not suggested that all the surplus copper in sight at the present time can be taken care of by means of this scheme, but there is certainly an opening for some of it, and the scope of these sales may widen as the months go by. It is reported that the Ministry of Supply has placed orders in the States to supplement this country's large production, and it is quite possible that this plan will continue.

In spite of everything, "dollar" copper does not find itself in a very favourable position, for this country is drawing such huge tonnages from Empire sources that additional quantities are not likely to be wanted for current needs. While U.K. purchases may perhaps include a certain amount of copper from the Belgian Congo, it now seems rather doubtful whether any American brands will come to Britain, even though there are balances remaining on the French contracts. To all thinking people one thing must be apparent, and that is the necessity to find a means of absorbing this surplus metal at a price which will enable the great South American copper industry to continue to function successfully. Much of the economic structure of the world has been crushed by the German onrush, and what remains is the joint responsibility of those who carry on the struggle.

B.S. Specification for Carbon Steel Castings

The British Standards Institution has just issued a revised specification for carbon steel castings, as indicated below. The complete specification is obtainable on application to the British Standards Institution, 28, Victoria Street, London, S.W.

Carbon Steel Castings (B.S. No. 592) (price 2s. 3d., post free).—The revised specification covers steel castings for ships and for marine-engine and general engineering purposes and supersedes B.S. Specifications Nos. 30-107, 592-1935 and 5028-1924. Three grades of castings are included, *viz.*, those having a tensile breaking strength of 28 to 35 tons per sq. in., 35 to 40 tons per sq. in., and a non-test grade, *i.e.*, castings which comply with the specification excepting that sulphur and phosphorus determinations and tensile and bend tests are not required.

Catalogue Received

Cast-Iron Pipes and Specials.—The Staveley Coal & Iron Company, Limited, near Chesterfield, has just issued a complete catalogue covering the whole range of cast-iron pipes and specials. It is an extremely ambitious production, extending to over 350 pages, yet quite devoid of "padding." Space, however, has rightly been found to describe briefly both the sand-spun and metal-spun processes. These notes are preceded by a short history of the company (which was one of the first to be registered under the Act of 1863) and its general industrial activities. There are some interesting notes on the company's housing scheme, and it appears that the 1,800 new houses it has built recently are supplied with constant hot water from a central station in each village. The insulation is such that a temperature decrease of only 15 deg. F. is shown at the end of the circuit. The complications of the cast-iron pipe trade are well portrayed in this catalogue, for roughly one-third is devoted to "specials." As the internal diameters range almost inch by inch from 2 in. up to 48 in., and for each size such castings as sockets, spigots, bends, elbows, tees, crosses, angle branches, collars, tapers and caps have to be listed, the proportions which the book assumes can be well imagined. Obviously, some compression could have been effected, but only at the expense of creating unwieldly and consequently unattractive tables. The reviewer congratulates those responsible for the production of this monumental work, the preparation of which was well advanced at the time of the outbreak of the war. The volume deserves careful preservation in every library of trade literature, for the assembled data are of a lasting quality.

American Steel Castings

(*Continued from page* 133.)

The control of moulding sand as set out in the Paper is quite novel, for whilst only two grades of silica sand are bought, the number of materials is brought up to six by the inclusion of steel bond sand, steel heap sand, used sand-blast sand and bentonite. Basically there are only four types of sand, but from them are derived twenty-six types of mould surfaces as a result of drying treatments (related to time in the case of air-drying), and surface preparation. Core-making materials are dealt with similarly, and as a result the properties of three basic sands have been established and standardised after submission to eighteen different surface treatments and time exposures. Mr. Lorig, of the Battelle Memorial Institute, has been plead-

(*Continued at foot of next column.*)

Random Shots

One of the minor problems of this war is to know what to say when the best lad you've got in the place goes off for his military medical examination. If you very heartily wish him good luck and hope the doctors pronounce him A1, you will probably be accused of wishing to get rid of him. On the other hand, in your natural sorrow at the prospect of losing a good worker, you can hardly wish that the medical board will class him as a C3 physique. *Que faire?*

* * *

"Everybody's knittin'," sobbed a youngster in the park the other day. "And I've no one to play wiv! Farver's sittin' over there knittin' his brows; Muvver's at home knittin' socks; and me big bruvver's gone and joined the Air Force and now 'e's a' nittin' the Garmins!"

* * *

To turn to other more pleasant affairs, it seems that if there is one thing of which the Americans and the English share a common appreciation, it is of each other's slanguage, for on "Marksman's" desk are two letters from America to testify to the fact. The first comes from Dr. Jim Mackenzie who answers that soul-rending appeal which appeared in this column some weeks ago for the meaning of the word "doodlebug." The mere Englishman can be forgiven his ignorance, as the word, it will be remembered, even stumped Dr. Schwartz. At last the matter has been settled by Dr. Jim, who says that "a doodlebug is a device used to locate magnetic minerals and iron pipes in the ground. It is used considerably in the oilfields and on the long pipe-lines prevalent for the transportation of oil and gas in that country. It apparently gets its name from the childish game of blowing or dropping sand on the doodlebug hole to make him come out and show himself."

* * *

The second letter is from Mr. Vanick, of the International Nickel Company of New York, who says that he has been much amused by the quiz that has been conducted in this column over the origin and meaning of American slang. He encloses a further contribution, which he hopes will serve as a little diversion in England, where everyone is so engrossed in the war effort. It takes the form of a page cut out of the New York "Herald Tribune," headed "What kind of a language *is* this?" The answer, apparently, is to be found in the forty-year-old prophecy of Mr. Dooley, who said, "When we Americans get through with the English language, it'll look like it has been run over by a musical comedy." Then follows a veritable bumper harvest of Americanisms, some of which, *mal à dire*, fall from the lips of the rising generation over here as if they had been born and brought up in Noo York City. Here, as in America, the kids tell each other to "scram," but an irate parent of these Blessed Isles is still sufficiently insular to tell the young offender politely "to get out of here." "Phony," on the other hand, seems to have been adopted over here solely by the older generation. Such phrases, however, as "The whole ball of wax," "very spotty dealer situation," "corned willy," "Hi, Ya, kid," "jallopy," and "jeepers" still sound distinctly foreign to the English ear. Aw, shucks, Mr. Vanick, what *do* they all mean?

"MARKSMAN."

(*Continued from previous column.*)

ing for more fundamental research for the foundry industry. For our part we would welcome a more intense application of such fundamental data as are available to the industry and of which this Paper is such an outstanding example.

Properties of Commercial Pearlitic Malleable Iron*

By C. H. LORIG (Metallurgist, Battelle Memorial Institute)

Pearlitic malleable iron is distinguished from the standard malleable by the character of the matrix. This distinction resides in the fact that pearlitic malleable contains some carbon in the combined form, whereas the standard malleable contains, generally, only a minute quantity of combined carbon. The pearlitic malleables differ in properties as their matrices differ. The significant amounts of combined carbon in pearlitic malleable make it stronger, harder and less ductile than standard malleable iron.

The term "pearlitic" describing the class of malleable iron mentioned in this Paper is generic and is by no means identified only with malleable irons in which the matrices contain pearlite, but refers to irons manufactured to contain more or less a prescribed amount of combined carbon in any form. Thus Z-Metal, for example, which is characterised by a spheroidised

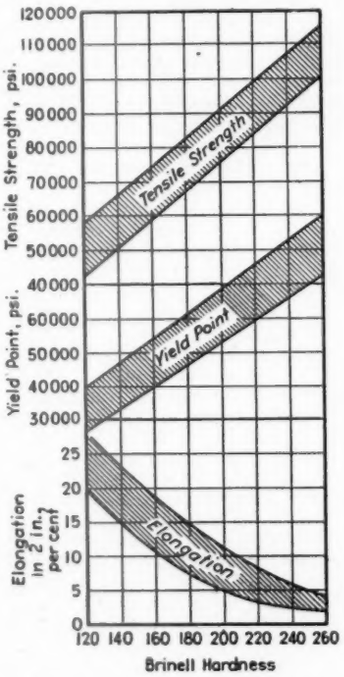

FIG. 1.—RELATIONSHIP OF TENSILE PROPERTIES OF COMMERCIAL PEARLITIC MALLEABLE IRON TO BRINELL HARDNESS.

form of combined carbon in the matrix, comes within the classification of so-called pearlitic malleable iron.

Manufacture of Pearlitic Malleables

Pearlitic malleables are made from white cast irons which are usually of standard malleable analysis or sometimes modified by alloying additions. To render the irons pearlitic three methods are now in commercial use. The irons, both of the unalloyed and alloyed types, may be given one of two special heat-treatments which comprise, in one case, of arresting the graphitisation during the second stage, thus retaining some carbon in the combined form, and in the other, of completing the graphitisation and subsequently heating above the lower critical point to recombine some of the carbon. In the third method alloying elements are added and in such amounts as would fit the irons into the regular anneal.

The alloying additions are employed to control the amount of combined carbon retained in the matrix. To a lesser extent they are used to modify the properties. Among the retarding elements are manganese, the most widely used of all elements and frequently employed in amounts somewhat above 0.6 per cent., molybdenum which seldom exceeds 0.5 per cent., and chromium which is very infrequently used and then in amounts considerably under 0.5 per cent. To counteract the stabilising effect of chromium and to speed the decomposition of massive cementite in the first stage of malleablising, additional silicon is sometimes used. The only other commonly employed element is copper, often added to increase corrosion resistance, though it also affects the malleablising treatment favourably and increases the yield point, tensile strength and hardness of the iron.

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Ladle Additions Beneficial

The additions are usually made in the ladle, later to improve the structure and properties of the annealed white iron by their alloying effects. In air-furnace practice the ladle treatment also produces effects which cannot be realised when the same amount of alloys is added to the original charge. The late addition of manganese, for example, produces more beneficial results than if the additional manganese was added to the charge.[1] Ladle additions are desirable in most commercial operations since standard malleable and pearlitic malleable are usually produced from the same heat. In a few cases where the electric furnace and other types of small melting units are employed no ladle additions are used. One manufacturer has taken advantage of the fact that iron melted in the electric furnace responds differently in the anneal from air-furnace iron. His annealing practice is designed and the composition of the iron is chosen accordingly. In this case the combination of electric furnace melting and continuous annealing in a tunnel kiln is considered of prime metallurgical importance in control of analyses and physical properties.

There are, according to a tabulation in the Symposium on Pearlitic Malleable Cast Iron,[2] from fifteen to seventeen distinct pearlitic malleables in common use, some of which differ in manner of production rather than in properties. This symposium classified pearlitic malleables for the purpose of study and discussion into two major divisions, namely, division I, metal produced by interrupting graphitisation before completion, and division II, metal produced by reheating completely graphitised alloys. The divisions may be further subdivided into class A, metal having a composition similar to that of malleable iron in which the retention of combined carbon is due to a shortening of the annealing cycle, and class B, metal to which various retarding elements have been added to secure a retention of combined carbon even with reasonably extensive heat-treatment. The classification further groups the irons according to various metallographic forms of the combined carbon and to the distribution of the ferrite and decomposed austenite.

By regulating the heat-treatment of pearlitic malleables containing no primary cementite, it is conceivable that materials of almost any desired combined carbon content up to eutectoid composition can be produced. Metallurgically the products made by interrupting the graphitisation and by reheating the completely malleablised iron above the A_1 point differ,

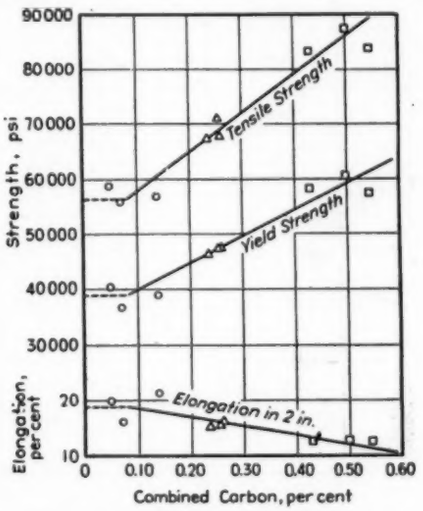

FIG. 2.—TENSILE PROPERTIES OF BARS AS AFFECTED BY COMBINED CARBON CONTENT (D. P. FORBES).

principally in microstructure, when recombination of carbon in the reheated, malleablised casting is incomplete. The differences in microstructure disappear, however, when recombining of the carbon reaches the eutectoid carbon content, and when the metal is alike in composition and subsequent treatments are the same.

Both the above heat-treating methods for producing pearlitic malleables lend themselves to the making of materials with the same range of properties. By variations in each of the heat-treating methods, the form and amount of carbides may be varied. It becomes possible, therefore, to produce different types of pearlitic malleables with physical properties that vary from those of standard malleable to those with a tensile strength about 55 tons per sq. in. and an elongation of 2 to 3 per cent.

As a rule, tensile strength and elongation or ductility vary inversely, though this relationship is by no means precise, for ductility is more dependent on the form of the combined carbon and its distribution in the matrix than is the tensile strength. Tensile strength and combined carbon content of pearlitic malleables appear to be closely related, and each in turn seems to bear a close relation to the hardness. This is not the case with ductility. Evidence thus far obtained seems to bear out the point

D

* Slightly abridged from a Paper presented to the forty-third annual meeting of the American Society for Testing Materials at Atlantic City, N.J.

that a matrix in which the combined carbon is spheroidised is, generally speaking, more ductile than is a sorbitic matrix, and that the latter is more ductile than is a coarsely lamellar pearlitic matrix. These variations in ductility with microstructure are noted for irons of approximately identical tensile strengths and combined carbon contents.

Correlation of Tensile Properties of Commercial Pearlitic Malleables

It is not surprising, therefore, that in the production of pearlitic malleables considerable ingenuity has been exercised in seeking to heat-treat and to make compositional changes, on a scale feasible in practice, so as to obtain the highest ductility concomitant with the desired tensile strength. Much secrecy still surrounds the heat-treatments and compositions being employed for some of the products.

Fig. 1 was prepared by plotting tensile properties against Brinell hardness, using available published data. The bands, extended to include properties of standard malleable, are at best only qualitative indications of trends in properties with hardness and should be accepted in that light.

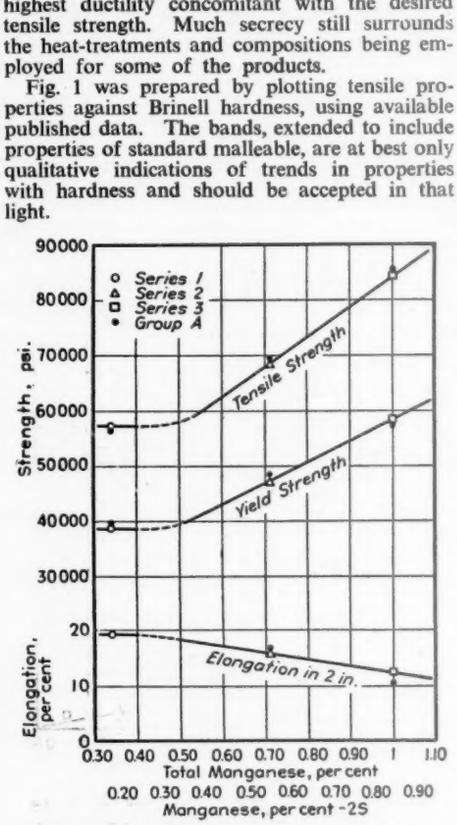

FIG. 3.—TENSILE PROPERTIES OF BARS AS AFFECTED BY MANGANESE CONTENT (D. P. FORBES).

Both tensile strength and yield point values varied in direct proportion to changes in hardness within the range of hardness covered. Only a few points fell outside the bands. These exceptions were principally values which were minimum figures for the irons or were for irons in which the carbon contents deviated considerably from the average. The curves indicate that the amount of graphite and the number of graphite nodules have an important effect on tensile properties, while they have a less important effect on the hardness. This is well known. A somewhat better correlation doubtless could have been obtained with data from specific irons in which carbon contents were closely alike.

A proportionately greater scatter in values giving a proportionately broader band was secured when elongations were plotted against Brinell hardness values. This was expected in view of the dependence of ductility on the form of the carbide and the degree of homogeneity of the matrix, that is, on the microstructure.

Fig. 1 shows that the various processes for producing pearlitic malleable irons give substantially the same tensile strength and yield point for a given Brinell hardness for any one composition. The similarity between processes does not hold with respect to ductility, for variations in ductility are realised, irrespective of the hardness or strength, due to the different microstructures associated with the various processes.

Forbes[1] found a somewhat similar relationship between tensile properties and the combined carbon content as has been shown above between tensile properties and Brinell hardness. His data were secured on irons of almost identical analyses except for manganese. Manganese was employed to retain different percentages of combined carbon in the irons after they were graphitised, air-cooled from above the critical temperature, and spheroidised for 30 hrs. at 590 deg. C. In form, the combined carbon in the different specimens did not differ since it existed as spheroids. Hence a close relationship was also found between ductility and the combined carbon in the irons. Fig. 2 is reproduced from Forbes' Paper.

Effect of Alloying Elements

Forbes also showed the average properties obtained from the irons after the spheroidising treatment plotted as a function of the manganese content. These are given in Fig. 3. In this case a straight-line relationship was obtained between properties and manganese in the range from 0.50 to 1.0 per cent. This would be expected since the combined carbon content after spheroidising increased directly with manganese content. The influence of manganese on properties is apparently directly proportional to the power of manganese to retain combined carbon in the iron after spheroidising.

Other elements commonly used to retard second-stage graphitisation to obtain better regulation of carbon in the combined form are molybdenum and chromium. Chubb[11] reported some work on molybdenum in short-cycle, heat treated malleable iron, and Hall[12] gave interesting data on chromium additions.

Chubb determined the properties of three heat-treated irons of the following analysis:

Iron.	T.C. Per cent.	Mn. Per cent.	Si. Per cent.	Mo. Per cent.
No. 1	2·15	0·60	1·94	Nil
No. 2	2·03	0·60	1·94	0·41
No. 3	1·98	0·44	1·92	0·78

They were held at 940 deg. C. for 4 hrs., cooled in the furnace to 760 deg. C., and quenched in oil. The two molybdenum irons were tempered at 730 deg. C., iron No. 2 being maintained at temperature for 3 hrs. and iron No. 3 for 1 hr. The unalloyed iron was tempered at 830 deg. C. for 2 hrs. The tensile properties of the irons were as follow:

	No. 1.	No. 2.	No. 3.
Tensile strength, tons per sq. in.	34·4	41·2	44·8
Yield point, tons per sq. in.	26·1	33·6	39·4
Elongation in 2 in., per cent.	4·5	6·5	5·1
Yield ratio	75·8	81·6	82·6
Brinell hardness	194	217	255

The tensile strength and yield point values are well within the bands of Fig. 1. Molybdenum like manganese improves the strength and yield point principally by increasing the combined carbon and hence the hardness of the iron. Since the matrix was greatly refined by the molybdenum it was not surprising that the alloyed irons showed relatively high ductility values. The increase in yield ratio with molybdenum content may also be attributed, at least in part, to the refinement of the matrix.

The work of Hall[12] on chromium in malleable iron covered the range of chromium additions up to 1.15 per cent., with additional silicon to counteract the tendency for the chromium to form stable carbides. The irons were given a standard anneal of 120-hr. duration. The range of properties obtained with chromium varying from 0 to 1.15 per cent. and with corresponding variations in silicon from 1.0 to 2.0 per cent. was as follow: Tensile strength, 24.1 to 36.1 tons per sq. in.; yield point, 16.7 to 27.9 tons per sq. in.; elongation in 2 in., 18.5 to 2.5 per cent., and Brinell hardness, 131 to 223.

The matrices of the chromium-containing irons were principally finely laminated pearlite with a few patches of ferrite surrounding the temper carbon nodules. A considerable amount of primary cementite was retained in the high-chromium irons. This perhaps accounts for the fact that the tensile strength of the series of irons increased with chromium up to about 0.60 per cent. and then decreased with higher chromium contents. In the range from 0 to 0.60 per cent. chromium, however, the tensile properties were in line with those for commercial pearlitic malleables at the same Brinell hardness levels. Small additions of chromium appear to affect the properties of pearlitic malleables in somewhat the same way as increases in manganese or as additions of molybdenum.

Excepting the few cases where pearlitic malleables may contain extra silicon, the only other important alloying element or addition used is copper. Its chief effect is to increase the resistance of pearlitic malleable to corrosion in air and by certain corrosive media. Copper above about 0.50 per cent. raises the tensile strength, yield point and hardness; however, practically no quantitative information is available on the effect of copper on tensile properties of pearlitic malleables.

Other Properties of Pearlitic Malleable Iron

Impact Resistance.—Comparative impact tests[5] on Z-Metal and standard malleable iron resulted in the following range in impact values: Z-Metal, 30 to 15 ft.-lbs.; malleable iron, 15 to 7 ft.-lbs. The results were obtained on a special machine similar in design to the Charpy machine, but adapted for cast test specimens ½ by ½ in. in cross-section notched to a depth of ½ in. after annealing.

Machinability and Wear Properties.—The machinability of pearlitic malleable as a class is said to be better than that for other ferrous products of the same hardness. In this regard Joseph,[6] from comparative machining tests, indidated that ArMaSteel was from 20 to 40 per cent. more machinable than steel bar stock and drop forgings of the same Brinell hardness. ArMaSteel machined better at lower speeds using a greater feed. The number of castings of ArMaSteel per tool grind was from 20 to 100 per cent. greater than it was from similar parts made from forgings. There was also less wear on tools in broaching ArMaSteel and broaching pressures were lower.

Very few specific data on machinability of other pearlitic malleables are available. While the claims for the superiority in machinability of pearlitic malleables over forgings of the same hardness appear to find support in the machine shop, there is reason to doubt that all pearlitic

(*Continued on page* 145.)

TABLE 1.—*Corrosion Resistance of Z-Metal and Standard Malleable Iron.*

Type of material.	Salt water, 10 per cent. solution.	Mine water (coal).	Sugar-cane solution.	5 per cent. sulphuric acid.	25 per cent. tannic acid.	5 per cent. lactic acid.	5 per cent. hydrochloric acid.
Z-Metal with approximately 0·75 per cent. copper	0·016	0·00715	0·099	2·68	0·047	0·075	0·455
Standard malleable iron	0·052	0·1680	1·628	27·57	0·087	1·190	11·181

Application of External Chills in the Production of Steel Castings

By W. F. McKEE

(*Continued from page* 126.)

DISCUSSION OF RESULTS

For the purpose of discussion, consider the L, T, V, Y and X sections as located in casting in a manner that it is impossible to feed except through arms. They may be considered of indefinite length. The chills, of course, would be of corresponding length. The depth of section, theoretically, will make no difference in size and location in plan view of a defect. The chills also will be considered in plan view, and volume will not be considered for it would be as indefinite as the length of chill. All chills used on a casting were measured, and the surface in contact with the casting wall will hereafter be described as "contact surface." The combined area of all chills used on each casting will also be given. For ease of comparing effect of chills, one casting in each series was made without chills and will be shown as No. 1 casting in each group.

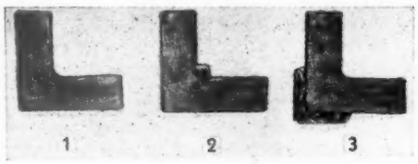

FIG. 6.—"L" SECTIONS WITH 1-IN. RADII.

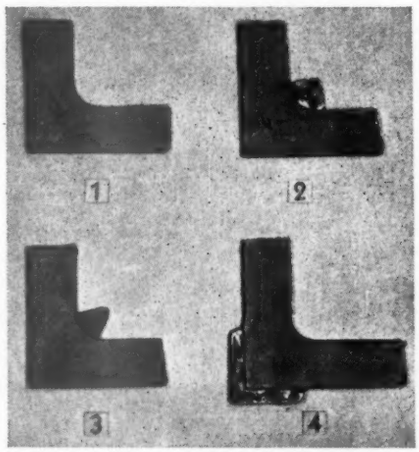

FIG. 7.—"L" SECTIONS WITH 2-IN. RADII.

"L" Sections

The "L" is the most common and most used of all junctions. Fortunately, it is also the easiest of all junctions to make solid by use of chills.

One-in. Radii.—Fig. 6 shows "L" sections with 1-in. radii used in inside corners. Fig 6 (2) shows a casting with crotch chill covering the entire radius. The casting shows no defect. The contact surface was 1.6 in., and the chill area 0.67 sq. in. Fig. 6 (3) was cast with a saddle-chill around the outside corner. The casting is sound. The contact surface is 7.5 in., and the chill area 6.8 sq. in. This is believed to be the better of the two chill applications because:—(1) It is the simplest chill to make to fit the surface; (2) so long as the chill does not extend too far out on the arms of casting, over-chilling cannot be produced, as is so easily the case with crotch chills, which will be shown in a later application; (3) it is well known that if the outside corner of an "L" section be broken by a radius that will cause the section to be slightly smaller at the junction than the arms, the section may be cast solid—this saddle chill acts directly upon the section that would thus be removed and allows arms to feed the section while solidification occurs.

Two-in. Radii.—Chill treatment of "L" sections with 2-in. radii is shown in Fig. 7. The specimen of Fig. 7 (2) was cast with a chill covering the entire inner radius. This was definitely too large or of improper design for the casting has a defect one-half as large as in Fig. 7 (1). The contact surface was 3.25 in., the chill area 3.7 sq. in. Fig. 7 (3) shows a chill that covered approximately three-fourths of the radius. Each edge of the chill is one-eighth of the radius removed from the tangent point, allowing arms to remain open and feed the section being chilled. The casting is solid. The contact surface is 2.25 in., and the chill area is 2.9 sq. in. The chill is definitely smaller than that of Fig. 7 (2), although it produced a sound casting. The saddle-chill was used on the specimen of Fig. 7 (4) and produced a sound casting, although the chill was the same size as one used on the section with 1-in. radius. The contact surface is 7.5 in., and the chill area 6.8 sq. in.

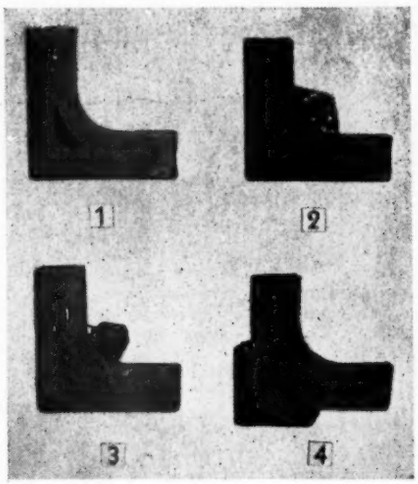

FIG. 8.—"L" SECTIONS WITH 3-IN. RADII.

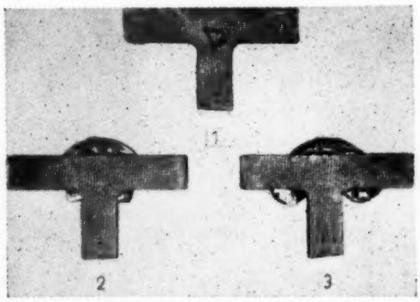

FIG. 9.—"T" SECTIONS WITH 1-IN. RADII.

Three-in. Radii.—Sections of "L" shape with 3-in. radii are shown in Fig. 8. Here again (Fig. 8 (2)) the crotch chill covering the entire inner radius failed to produce a sound casting because it caused the arms to freeze before the heavy sections could become solid. The surface contact is 4.5 in., and the chill area 6.0 sq. in. A chill covering three-fourths of the inner radius was used on the specimen of Fig. 8 (3). It produced a commercially sound casting, although there is a minor "spongy" area near the centre of the heavy section. The contact surface is 2.6 in., and the chill area 4.1 sq. in.

A saddle-chill was used on the specimen of Fig. 8 (4) producing a sound casting. It will be noted that this chill covers the outside wall of casting from a point opposite the tangent points of inner radius. This is, the author believes, the proper area to be covered by a chill of this type. The contact surface is 9.0 in.. and the chill area 9.2 sq. in.

"T" Sections

One-in. Radii.—Fig. 9 shows chills used on "T" sections with 1-in. radii. Fig. 9 (2) shows what may be considered as the conventional way of chilling such sections. The chills consist of two chills that cover the entire radius placed in the corners and large flat chill placed across the top of the "T." This casting is commercially sound although there is a very slight "spongy" section almost between crotch chills. The contact surface is 9.25 in., and the chill area 7.9 sq. in.

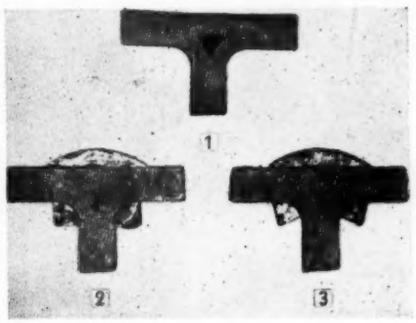

FIG. 10.—"T" SECTIONS WITH 2-IN. RADII.

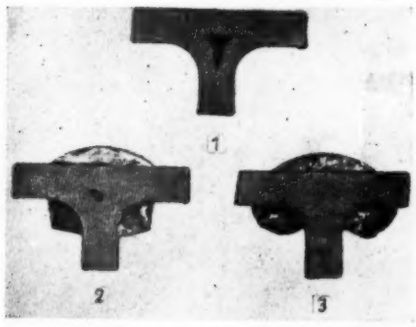

FIG. 11.—"T" SECTIONS WITH 3-IN. RADII.

In Fig. 9 (3) the crotch chills are placed more on the arms and cover about three-fourths of the radii. This was done to try to avoid freezing the leg so that the chilled section would be fed through the leg. The casting is solid. The contact surface is 12.75 in., and the chill area 11.8 sq. in.

Two-in. Radii.—Sections of "T" shape with 2-in. radii are shown in Fig. 10. Section 10 (2) was chilled with conventional chills that covered entire radii at the leg junction together with a large chill across the top of the "T." The defect found is almost as large as in unchilled specimens, due, it is believed, to the fact that size and location of chills caused the arms to

freeze and shut off all feed. The contact surface is 15.25 in., and the chill area 12.9 sq. in.

Section 10 (3) was chilled with crotch chills that covered the radii from tangent point on the arms, three-fourths the distance to the tangent points on the leg. These chills were designed to have sharp re-entrant angle of sand between chills and the wall of the leg. This helped to dampen the effect of the chill upon the leg and allowed it to feed necessary metal to the larger section. The large chill was also used across the top of the "T." The section is sound. The contact surface is 14.25 in., and the chill area 11.9 sq. in.

Three-in. Radii.—Fig. 11 shows "T" sections with 3-in. radii. This section is extremely hard

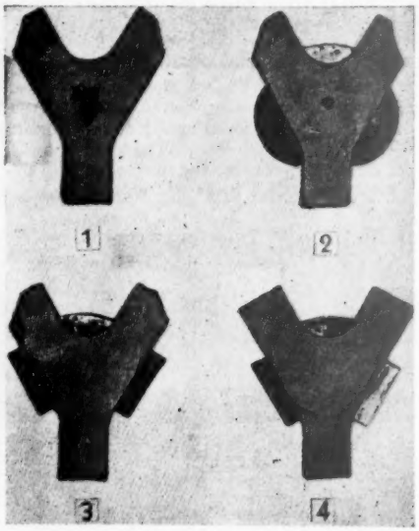

FIG. 12.—"Y" SECTIONS WITH 3-IN. CROTCH RADII.

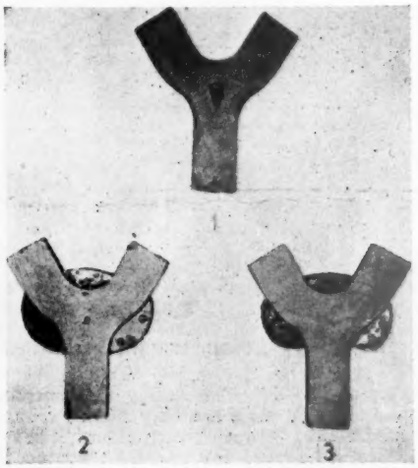

FIG. 13.—REDESIGNED "Y" SECTIONS.

to cast sound. Such large radii form sections at the junction so heavy that abnormally large chills must be resorted to in order to chill this excess metal. Conventional chills used on Fig. 11 (2) did not produce a sound casting. The defect is approximately one-half as large as in the unchilled specimen. The contact surface is 18.25 in., the chill area 17.9 sq. in. Heavy chills, acting mostly upon the arms and covering approximately three-fourths of the radii on the leg, together with the chill across the top of the "T," produced the sound casting in Fig. 11 (3). The contact surface is 18.75 in., and the chill area 25.0 sq. in.

"Y" Sections

Sections of "Y" shape with 3-in. radii in the crotch present a rather heavy section to be chilled; however, it is not as difficult to chill these successfully as "T" sections with large radii, because chills may be placed more in direct contact with the section to be chilled. Fig. 12 illustrates the results of some attempts to chill such a section. The specimen of Fig. 12 (2) was cast with a crotch chill covering the entire crotch radius, also with large chills covering the entire wall of the casting adjacent to the heavy section and extending over the entire radii at the junction with the leg. The defect, while small, was critical, proving to be a complete cavity. The contact surface is 15.25 in., and the chill area 19.0 sq. in.

The same size and shape crotch-chill was used on the specimen of Fig. 12 (3) as was used on Fig. 12 (2), but plate chills were used on the sides of the heavy section. They do not extend down to the leg junction. A small defect appears directly between the ends of chills, just

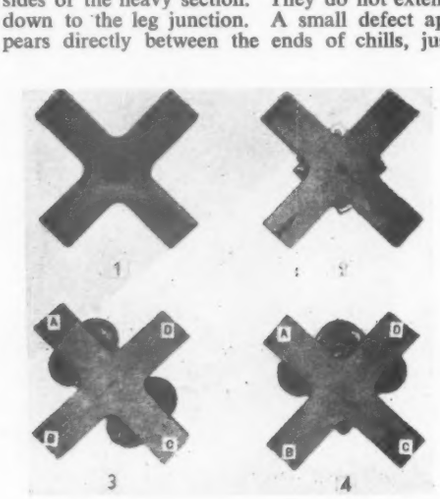

FIG. 14.—"X" SECTIONS WITH 1-IN. RADII.

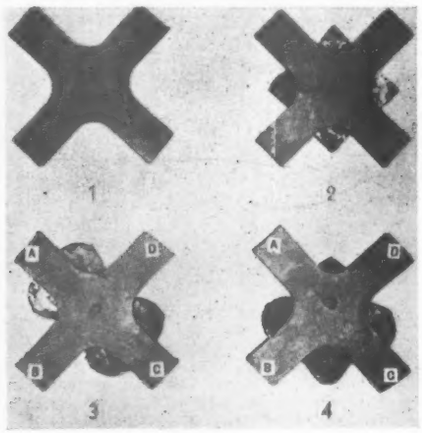

FIG. 15.—"X" SECTIONS WITH 2-IN. RADII.

above the junction with the leg. The contact surface is 13.25 in., and the chill area 12.9 sq. in.

Exactly the same chills were used on Fig. 12 (4), but plate chills were placed almost down to the leg junction. The location of the chills is most important. The casting was sound. The contact surface is 13.25 in., and the chill area 12.9 sq. in.

Should the design of the "Y" be changed as demonstrated in Fig. 13, it becomes a much simpler section to chill. The crotch retains the 3-in. radius, but the sides that were straight are now curved inward, eliminating much of the metal that formed the junction of the design of Fig. 12. A crotch-chill, covering the entire radius, together with side-chills that cover the casting wall from the point opposite the tangent point of the crotch radius to the tangent point of the radii on the leg were used on the specimen of Fig. 13 (2). The defect was small but it was a clear cavity. The surface contact is 14.75 in., and the chill area 15.2 sq. in. The same chills were used on the specimen of Fig. 13 (3) as those used on Fig. 13 (2), except that the ends of the outside chills, that covered the radii at the leg junction, were removed so that the chills covered about one-half of the radii. The casting produced was sound. The contact surface is 12.75 in., and the chill area 13.5 sq. in.

"X" Sections

The cross is perhaps the most difficult of all sections to cast solid without feeding direct. The junction of four sections of metal in this form forms the largest possible section of metal exposed to the least amount of mould wall through which the heat may be dissipated. Chilling is made difficult for the same reason; not enough chill surface may be exposed to the heavy section created by the junctions without freezing off arms and preventing feed.

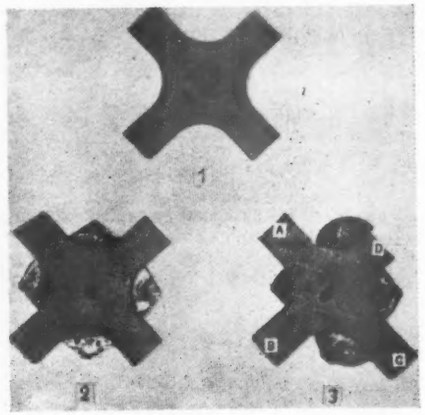

FIG. 16.—"X" SECTIONS WITH 3-IN. RADII.

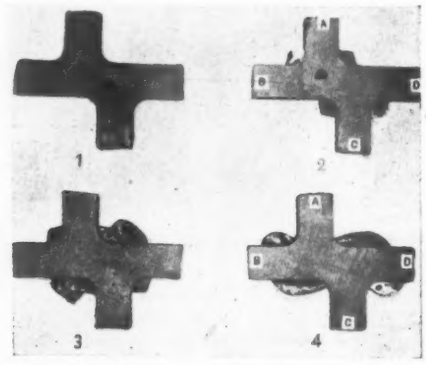

FIG. 17.—STAGGERED "X" SECTIONS WITH 1½-IN. RADII.

One-in. Radii.—Chill treatment of "X" sections with 1-in. radii is illustrated in Fig. 14. Chills that may be considered conventional were used on the specimen of Fig. 14 (2). They covered the entire radii. The defect was a complete cavity. The contact surface is 6.0 in., the chill area 4.1 sq. in.

On the specimen of Fig. 14 (3), an attempt was made to chill the junctions of arms A and C completely and allow junctions of arms B and D to solidify as a straight section. The chills covered one-half of radii, and there was a very acute angle of sand between the chills and arms B and D. The results might have been more

gratifying if this "hot spot" of sand could have been eliminated. The casting was commercially sound, for it will be noted the defect is no more severe than the centre-line weakness visible under letter on arm B. The contact surface is 11.25 in., and the chill area 14.1 sq. in.

From a study of the results achieved in this casting, it seemed desirable to get more chill surface in contact with the heavy metal section, and this was attempted in Fig. 14 (4). Here the desire was to chill junctions A and D completely and treat B and C as an "L" section. The same type chill, as used on Fig. 14 (2), was placed on the outside of arms A and D at their junction, and a large chill was placed between the arms. A conventional radius chill was placed between arms B and C. The casting had no cavity, although a "spongy" area developed between junctions B and C. It was not serious, for it may be seen that it is not as large as centre-line weakness in arm C. The contact surface is 17.25 in., and the chill area 17.2 sq. in. As the radii at junctions of the arms of "X" are increased the possibility of a sound casting without the use of direct feed becomes more impracticable.

Two-in Radii.—In Fig. 15, the "X" sections have 2-in. radii. The same chilling effect was applied as in Fig. 14, only with larger chills designed to fit the larger sections. The results were not at all satisfactory. It appears the section created by these junctions is so large it is not possible to apply sufficient external chills and keep the arms open to feed the section until it becomes solid. For Fig. 15 (2), the contact surface is 12.25 in., and the chill area 14.0 sq. in. For Fig. 15 (3), the contact surface is 15.0 in., and the chill area 19.2 sq. in. For Fig. 15 (4) the contact surface is 16.0 in., the chill area 19.1 sq. in. It will be seen that these chills are so large as to be difficult to hold in place either in the mould wall or in the core.

Three-in. Radii.—Fig. 16 shows the "X" section with 3-in. radii. Here again is demonstrated the impracticability of chilling a section such as this with external chills alone. The chills used are almost equal in volume to the casting, but the casting still has serious defects. For Fig. 16 (2), the contact surface is 18.0 in., and the chill area 23.7 sq. in. For Fig. 16 (3), the contact surface is 17.75 in., the chill area 24.3 sq. in. If the design of the "X" can be changed and the arms staggered as much as the thickness of the arms, the problem of producing a sound casting is made more simple.

Staggered Cross-Members

Fig. 17 shows a staggered "X" with 1½-in. radii and the chill treatment necessary to produce a sound casting. Fig. 17 (2) has small chills covering the radii. There is a definite shrink at the junction of arms A and B, while the junction of arms C and D is sound. Both sections had the same amount of chills. The only reason advanced as to why one section is solid and the other is not, is temperature gradient. The casting was probably poured through either arm A or B, and their junction became more heated than the junction of C and D. The contact surface is 9.0 in., and the chill area 5.8 sq. in.

Fig. 17 (3) shows what may be considered a conventional way of chilling this section. It is chilled much like a "T" section. Small chills cover the entire radii at the junction of the legs, with larger chills covering opposite radii and side of the arms opposite the junction of the legs. The casting shows small defects at the leg junctions. The contact surface is 15.0 in., the chill area 15.4 sq. in.

The specimen of Fig. 17 (4) is chilled much in the same way as it was found necessary to chill "T" sections with larger radii. The chills cover about one-half of the radii and legs A and C are left open to feed the sections being

(*Continued on page* 145.)

Influence of Copper on High-Carbon Cast Iron*

By T. E. Barlow.

Knowledge of the effects of the different alloying elements on the structure and properties of grey cast iron is steadily increasing as the result of extensive study by the producers of these elements, as well as by the foundries themselves. The use of individual alloying elements to improve the properties of grey cast irons is well established. The tendency to-day is to pay close attention to carbon and silicon contents and to strive for a balanced composition, using, if necessary, two or more alloying elements in combination, to obtain the desired results in the most economical manner.

Copper is a comparative newcomer in the small group of elements used commercially as alloy additions to cast iron. The successful experience of the Ford Motor Company, the Allis-Chalmers Manufacturing Company, and several other large foundries where copper has been used for years has attracted widespread attention. Systematic engineering data are needed, however, so that the foundryman interested in the production of copper alloy cast irons can apply this commercial experience in his own practice over a wide range of engineering irons.

Recognising this need, the copper industry is conducting an extensive programme of research and development at Battelle Memorial Institute. The article from which this extract is taken has been based upon unpublished progress reports of this work by C. H. Lorig and E. C. Kron of Battelle Memorial Institute.

As part of the programme, an investigation was made of the effects of copper on the properties of grey cast irons of different carbon and silicon contents. These experiments were planned to cover a wide range of compositions so that an indication of the interrelations of the copper, carbon and silicon contents might be obtained. An indirect arc electric furnace was used as a convenient means of producing the irons under carefully controlled conditions.

The melts were heated to about 1,540 deg. C. in the furnace, poured into ladles and held until the temperature had dropped to 1,400 deg. C. before casting.

The information obtained is useful as a guide for ordinary cupola practice, but the numerical values for the various properties of the different irons may, of course, be somewhat different for cupola metal. It is planned to supplement these results with a similar investigation of the more useful copper alloy cast irons as made in the cupola under shop conditions.

Four series of cast irons were prepared. These are:—(1) High-carbon, containing from 3.30 to 3.44 per cent. C and 0.63 to 2.50 per cent. Si; (2) medium-carbon, with 3.07 to 3.20 per cent. C and 0.68 to 2.61 per cent. Si; (3) low-carbon, with 2.80 to 2.90 per cent. C and 1.09 to 2.52 per cent. Si; and (4) alloyed, containing from 3.12 to 3.23 per cent. C, and 1.48 to 1.74 per cent. Si with various combinations of nickel, chromium, molybdenum and vanadium.

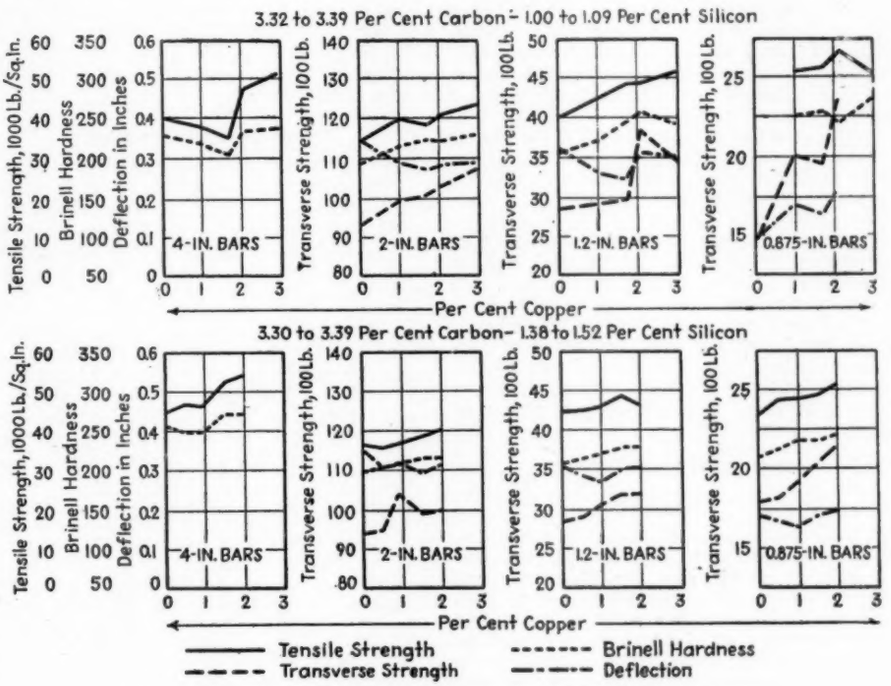

Fig. 1.—Effect of Copper on Properties of High-Carbon Cast Iron.

Values were obtained from duplicate bars in all cases. Two tensile bars were cut from each 4-in. test-bar. The Brinell hardnesses were taken midway between the centre and the surface of all bars. The unnotched impact values were determined with a Charpy-type machine on the broken halves of the 0.875 and 1.2 in. dia. test-bars. In this way, a measure of the influence of section size on the effects of copper could be indicated.

High-Carbon Cast Irons

The effects of copper on the properties of the 1.00 to 1.09 per cent. and the 1.38 to 1.52 per cent. Si grades in the four sections are plotted in Fig. 1.

The trend in properties with copper content appears to be characteristic for each silicon group of the series. The trend in tensile strength, transverse strength and Brinell hardness is upward with increasing copper contents. The deflection is affected only slightly, in general trending toward lower values as the copper content is increased. The influence of copper is equally effective in the four sizes of test-bars.

* Extracted from "Metals and Alloys," July, 1940. The author is Metallurgical Engineer with the Copper, Iron and Steel Development Association, Cleveland.

The Electric Arc Furnace in Industry*

By W. E. MOORE

Although much information is available about electric-furnace operation, many people do not appreciate that in the ingot field the modern top-charge rapid-type electric furnaces are in competition with the open-hearth furnace for producing ordinary carbon steels. There are now 12 companies in the United States with rolling mill operations on common quality steels where the sole source of ingots is the electric furnace. The electric furnace is, of course, distinctly superior to the open-hearth furnace for the production of alloy steels such as the stainless, etc., where, due to its very great flexibility of control and accuracy of operation, such close analysis can be more cheaply produced than by any other process. Since 1908, the electric furnace has gradually supplanted the crucible until to-day, for all practical purposes, 100 per cent. of the tool steels produced are so made.

In the casting field the electric furnace is beyond competition with the open hearth for ordinary foundry steels, particularly so in the foundry making medium- and small-size castings. The electric furnace has also made rapid advances in the production of high-grade iron castings and is regularly used for work such as automobile cylinder liners, camshafts, brake drums, piston rings and other parts. The flexibility of the modern electric furnace makes it especially adaptable to the manufacture of continuous castings such as centrifugal gear blanks, tubes, die castings, and parts of that character. It has also been used in the development of centrifugal cast-steel gears.

Electrodes

A factor which has been of material aid to the development of the electric arc furnace has been the advancement made in electrodes. Carbon electrodes have been markedly improved in quality of material as in the joint fitting and finishing. They are so much better as to electrical conductivity and means of coupling that to-day they are no longer the handicap to operation that they were 25 years ago.

The graphite electrode has likewise been improved in texture and particularly in fitting and finish of the joints. The breakage at the joints has been considerably reduced by very careful finishing and by using extra strength material for the threaded jointing nipples. Graphite electrodes to-day are available in sizes up to 20 in. and extruded carbon electrodes are manufactured in sizes up to 40 in.

Larger carbon electrodes for large smelting furnaces are made in sizes up to 3 m. in dia. by the well-known self-baking Soderberg process, which consists of constructing a continuous electrode within a sheet-metal casing, built section on top of section. These electrodes permit the use of cheaper carbon, and for large smelting furnaces, particularly ferro-alloy and carbide furnaces, are economical in some cases, though the first cost of the installation is considerably greater than that of the jointed electrode furnace plant. These electrodes, however, are not well adapted for steel-melting furnaces of the tilting type, although they have been so used in some cases.

Furnace Linings

Carbon blocks are now available for use as refractories and linings for electric furnaces and have a useful place in smelting furnaces for ferro-alloys, carbide, phosphate, etc. They are obtainable in many shapes, at prices that are competitive, considering their desirable qualities.

Another advance in the electrode-furnace field has been the improvement in refractories. The manufacture of silica blocks has made progress both as to accuracy of shape and freedom from spalling. The production of high alumina bricks has made marked progress and such bricks are especially useful in furnaces that operate on an occasional heat basis or are of the smaller type of plant. The rammed type of refractory has also made progress and the mullite rammed mixtures are being used successfully in commercial practice on the smaller size furnaces. Fused mullite refractories have come into extensive use within the last 15 years and are particularly valuable for their resistance to solubility in slag. It is expected that they will, in the future, be more widely used in the electric arc furnace.

Faster Furnace Operation

There have been many detailed improvements in electric furnaces to speed up their operation, such as the rapid traverse of electrode arms, rapid tilting by hydraulic mechanism, rapid charging by roof lift-swing-aside mechanism, quick slagging by tilting backward for slagging through a wide open door instead of through the taphole of the pouring spout; properly shaped wall refractories and roof brick blocks so that the lining may be quickly renewed by ordinary labour instead of requiring the services of a skilled bricklayer; in fact, many furnaces to-day are re-lined on Saturday afternoon after taking off the Saturday morning heat and immediately cooling down with a hose.

Improved electrode clamps are having marked effect on the efficiency of electric arc furnaces. Clamps are now so constructed that they are readily and conveniently operated while the furnace is under heat. These clamps are also, to-day, so amply cooled that they produce a cooling effect on the electrodes, minimising the oxidation above the roof and thereby permitting the use of smaller electrodes.

Top-Charging

The top-charge mechanism, however, has been the greatest advance in the electric-furnace art. This was started during the last war, when a number of the "pull-back, top-charge" furnaces in the smaller sizes were built. These were the so-called "coffee-pot" type in which the roof was hinged at the rear and near the bottom of the furnace shell by means of a frame that supported the roof structure. It was then merely pulled back, producing first a sliding effect, then a lifting and backward motion. There were, however, many difficulties in this construction and it was particularly hard on roof refractories so that most of those furnaces have to-day gone out of use.

The next innovation was the shute-charging type furnace, in which the charging was done by means of a long sheet-metal box or shute in which the scrap was piled and which was then inserted in the charge door of the furnace and lifted by the crane as the furnace was tilted forward until the angle of repose was reached and the scrap was slid forward into the furnace crucible, resulting in a compact charge. The angle of repose was reduced in many cases by use of a vibrator on the shute for minimising the friction and thus allowing the charge to slide in without having to lift the shute very high. This method of charging, however, required a good grade of scrap properly cut into small pieces and it was not practicable for use with large or bulky scrap.

Lift-Swing-Aside Roof

The next improvement was in the lift-swing-aside roof in which the roof is lifted by means of an oil-pressure cylinder which engages the roof structure and after lifting the roof clear of the furnace, swings it about 90 deg. to one side, thus leaving the furnace crucible entirely open for rapid charging by means of an orange peel drop-bottom bucket. The swing mechanism is constructed to operate by means of a cam motion and a helical slot in the cylinder on the small- and medium-size furnaces. On the larger furnaces a separate oil-pressure cylinder engages gear teeth on the ram by means of a rack built on to its pistons. These lift-swing-aside roofs are very smooth and rapid in operation, being cushioned against shock in both directions, and, since they do not swing the roof and electrodes through a vertical angle, do not result in breakage of refractories or electrodes, which was found to be a difficulty with the old "coffee-pot" type of roof.

With the new swing-aside roof the roof is swung entirely clear of the furnace crucible so that it is practicable by means of the drop-bottom charge-buckets to drop an entire charge into the furnace at one operation. A very great advantage of the swing-aside roof top-charge furnace is the fact that the entire cubical capacity of the furnace crucible is available for scrap, whereas with the side-door type of charging of furnaces the scrap-holding capacity of the furnace was usually limited to the door level in the side of the furnace. In many cases this makes available only about half of the cubical capacity of the crucible.

Furthermore, the charging is much more rapid with the top-charge type of furnace than is possible with the side-door-charge furnace, even when a shute or charging machine is used, and the construction cost of the plant is very much less with the lift-swing-aside top-charge roof than with the side-door machine charging. The larger cubical charging capacity of the lift-swing-aside roof top-charge furnace is of great and growing importance as the scrap is tending toward more bulky light-weight scrap, particularly in view of the rapidly advancing production of flat steel from which many parts are being stamped to-day that were formerly made of forgings or castings. The scrap produced from flat steel in modern factories is invariably of lighter weight, and of greater bulk, but is otherwise of excellent quality for electric-furnace charges.

With the early furnaces scrap having an average weight of 135 to 150 lbs./cub. ft. was used; later this bulk was increased so that the weight was only 80 to 100 lbs./cub. ft., and to-day in many plants the scrap that is melted has a weight of only 35 to 50 lbs./cub. ft. The rapid swing-aside roof top-charge furnace also permits the use of larger scrap and saves money in cutting and torching. With the ordinary size top-charge furnace, scrap ingots and larger pieces can readily be melted without expensive cutting operations.

There have also been made a number of other types of top-charge furnaces, particularly in Europe, such as the Trundle furnace which has the shell mounted on rollers and by motor or hydraulic mechanism is pulled out from under the roof when the roof is lifted by means of a gallows frame carrying electrode drum hoist overhead; the reversal of this type is also in use, in which the roof is carried by means of a structural gantry crane which spans the furnace shell and by means of motors the roof is lifted by the gantry and then the gantry by other motors is rolled to one side to allow the furnace to be charged through the open crucible. Such top-charge mechanism has not attained the proportion of large sales.

(*Continued on page* 145.)

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Mechanical and Physical Properties of High Duty and Alloy Cast Irons

By J. W. DONALDSON, D.Sc.

The development of high duty and alloy cast irons and their use for many stressed and other engineering parts necessitate a thorough knowledge of all their properties. Before the development of such irons, a development which has taken place during the last fifteen to twenty years, a knowledge of the transverse strength and in some cases of the tensile and compressive strength of cast iron was considered sufficient for most engineering purposes. As a result, however, of the various experiments and researches which have been carried out, a wide range of cast irons, both plain and alloy, have been made available for a variety of purposes involving many other properties besides strength. It has therefore been necessary to determine those properties for such irons, with the result that numerous investigations have been undertaken and a large amount of data has accumulated not only for such properties as tensile, transverse, and compressive strengths, but also for elasticity, hardness, fatigue, impact, and shear strengths. Determinations have also been carried out on the thermal and electrical properties, yielding data on thermal conductivity, electrical resistivity, specific heat, and thermal expansibility. A knowledge of the data thus determined shows modern cast iron to be a reliable material for many engineering purposes and also indicates possibilities for its further development in the future.

TABLE I.—*Summary of British Standard Specification for General Grey Iron Castings—No.* 321—1938.

Standard diameter of test-bar.	Transverse rupture stress.		Deflection.		Ultimate tensile stress.	
In.	Tons per sq. in.		In.		Tons per sq. in.	
—	A.	C.	A.	C.	A.	C.
0.6 ..	25.1	19.9	0.07	0.06	12.5	10.0
0.875 ..	24.1	19.6	0.10	0.09	12.0	10.0
1.2 ..	23.1	18.9	0.15	0.13	11.0	9.0
1.6 ..	21.4	18.3	0.12	0.10	10.5	9.0
2.1 ..	19.6	17.7	0.15	0.14	10.0	9.0

Tensile and Transverse Strength

The average strength of grey cast iron some fifteen years ago (apart from a small production of certain engineering castings of 15 to 18 tons per sq. in. tensile strength prepared from mixtures of pig-iron and steel scrap or from refined pig-iron) is shown in the B.S.S. 321, published in 1928. This specification, principally the work of the Test-Bar Committee of the Institute of British Foundrymen, gives the tensile and transverse strength for two grades of grey iron castings. A round test-bar in three sizes, 0.875, 1.2 and 2.2 in., representing varying cross-sectional thickness of casting, was introduced for the first time in this specification. The varying of the test-bar with the thickness of the casting has since then been adopted in most other countries which issue specifications for cast iron.

In 1938 this specification was revised largely by the Cast Iron Sub-Committee of the Technical Committee of the Institute of British Foundrymen, as a result of certain difficulties which had arisen as to the size of the test-bar and the casting thickness. At the same time, resulting from the developments in cast iron, a new high duty specification for grey cast iron was also prepared. Summaries of these two specifications, No. 321—1938 and No. 786—1938, are given in Tables I and II. The principal alteration in the revised 1928 specification is the introduction of two additional sizes of test-bar. The term Modulus of Rupture in the older specification is altered to Transverse Rupture Stress in the new specifications. This method of expressing transverse strength in tons per sq. in. without having to give details of bar span and size is coming to be generally adopted.

The high duty iron specification covers three grades of cast iron and is similar to the lower grade iron specification in nearly all parts except in the actual test requirements. Only four sizes of bars are included, the smaller 0.6-in. test-bar being omitted. The specification is intended to cover all high grade engineering iron made by ordinary processes using varying quantities of steel scrap or refined iron; irons made by special processes, inoculation, superheating, etc., alloy cast irons, and heat-treated cast irons.

In the first Report of the Research Committee on High Duty Cast Irons for General Engineering Purposes of the Institution of Mechanical Engineers,[1] the development of high duty irons is reviewed, and results are given of mechanical tests on some twenty-one commercial irons manufactured by various processes for various purposes. In Table III, compiled from the data contained in this report, are given the tensile and transverse tests, together with other tests of a number of high duty irons both plain and alloys. In those tests the ultimate tensile stress is given in tons per sq. in. on a 1.2-in. dia. bar machined to 0.798 in. dia., and the transverse rupture stress is based on the breaking load at fracture of a 1.2-in. bar on 18-in. centres. All the tests are obtained from materials supplied by founders from ordinary commercial production. Tensile and transverse tests for high duty and alloy cast irons are also included in Table IV.

Deflection and Elastic Modulus

When cast iron is broken in transverse, a deflection takes place at fracture which is usually measured in inches on the standard span and is used as an index of ductility or toughness similar to elongation in tension. Deflection values included in the two British Standard Specifications, as the result of a large number of tests, vary from 0.06 to 0.21 and show that the deflection does not increase proportionally with the transverse strength. Values for representative high duty and alloy cast irons are given in Tables III and IV.

Pearce[2] has shown that the deflection in transverse of grey cast iron comprises two components, elastic deflection and plastic deflection or permanent set, and that elastic deflection varies comparatively little from iron to iron. As cast iron differs from steel and other alloys in possessing no well-defined elastic range in which a definite stress : strain relationship holds, there is no true elastic limit and difficulty is therefore found in determining the elastic modulus in tension, as the usual methods are not applicable. The elastic modulus has therefore to be measured from the transverse test, and this is done either by calculation from the deflection at 25 per cent. of the ultimate strength, at which load the plastic deformation is very small, or by separating the elastic deflection from the plastic deflection at the breaking load and using the elastic deflection obtained for D in the beam formula of elastic modulus. Values obtained for high duty cast irons by this method are included in Table III, and show the elastic modulus of those irons to vary from 17 $\times$ 10^{-6} to 33 $\times$ 10^{-6}.

This method of evaluating the elastic modulus adopted by Pearce differs from that used in the

TABLE II.—*Summary of British Standard Specification for High Duty Iron Castings—No.* 786—1938.

Standard diameter of test-bar.	Transverse rupture stress.			Deflection.			Ultimate breaking stress.		
In.	Tons per sq. in.			In.			Tons per sq. in.		
—	1	2	3	1	2	3	1	2	3
0.875..	25.9	28.9	33.0	0.11	0.12	0.13	15.0	18.0	22.0
1.2 ..	25.0	28.0	31.0	0.16	0.17	0.18	14.0	17.0	20.0
1.6 ..	24.0	27.0	30.0	0.13	0.14	0.16	13.0	16.0	19.0
2.1 ..	23.6	26.1	29.1	0.17	0.19	0.21	12.5	15.0	18.0

TABLE III.—*Composition and Properties of High-Duty Cast Irons (Research Committee of Institution of Mechanical Engineers).*

Type of iron.	Composition.									Ultimate breaking stress.	Transverse rupture stress.	Deflection on 18-in. span.	Elastic modulus.	Brinell hardness.	Single impact test.	Repeated impact test.
	T.C	Si	Mn	S	P	Ni	Cr	Cu	Mo	Tons per sq. in.	Tons per sq. in.	In.	Lbs. per sq. in. $\times$ 10^{-6}.	—	Ft.-lbs.	No. of blows to fracture.
Ordinary	3.06	1.32	0.57	0.133	0.76	—	Trace	—	—	18.0	28.6	0.19	18.9	241	8.5	647
Low carbon ..	2.65	2.39	1.49	0.079	0.23	—	0.07	0.06	—	17.9	34.3	0.13	20.6	259	8.3	665
Hot-mould.. ..	3.16	0.93	0.78	0.093	0.15	—	—	—	—	16.6	34.2	0.37	18.4	185	—	—
Heat-treated ..	3.10	0.97	0.77	0.092	0.148	—	—	—	—	23.7	40.2	0.28	16.6	295	—	—
Ni-Tensyl	2.86	1.51	1.23	0.084	0.08	1.75	Trace	Trace	—	23.2	41.3	0.26	19.3	268	17.5	24,900
Low alloy	3.18	2.06	0.92	0.103	0.17	—	0.21	0.21	—	19.4	31.6	0.13	18.6	241	9.2	2,248
Alloy	3.21	1.26	0.49	0.109	0.06	1.31	0.52	—	—	18.3	29.5	0.16	19.6	290	—	—
Alloy	2.91	1.50	0.90	0.073	0.16	0.16	0.12	0.16	0.81	20.6	32.3	0.19	—	260	—	—
Alloy	2.79	1.24	0.79	0.034	0.03	1.65	—	—	0.39	24.2	35.3	0.25	17.5	293	13.7	150,929
Heat and corrosion resisting ..	1.14	1.78	0.47	0.034	0.01	0.22	33.83	2.01	—	28.0	32.3	0.11	33.2	331	13.1	152,000

United States by Mackenzie,[3] who determined the modulus of elasticity by calculation from the deflection of a rectangular transverse test-bar at an arbitrary load of 1,000 lbs. or at a final breaking load, and from the method of Thum and Ude[4] in Germany, who determined the same property by dividing the transverse rupture stress by the total deflection at fracture. The various methods of determining the elastic modulus do not allow of comparison of the values of the different investigators, and there is need for a standard international test for the evaluation of this property. If a test such as that suggested by Pearce were adopted, data would be obtained regarding the elastic properties of cast iron which would be of value to designers and engineers in the wider application of these high duty irons.

Compressive Strength

The compressive strength of grey cast iron is one of its most valuable properties and comes in importance after the tensile and transverse strength. In many engineering and structural parts cast iron is used more often in a state of compression than it is in tension or subjected to transverse stress, so that a knowledge of compressive stress is of the utmost importance. Few systematic investigations have been carried out on the compressive strength of cast iron, but values for this property have been included in the Report of the Sub-Committee A3 on Impact Testing of the American Society for Testing Materials.[5] Compressive strength values for representative high strength cast irons from the latter report are included in Table IV. These values show that there is no direct relationship between the tensile and compressive strengths, but that the ratio between compressive strength and tensile strength varies inversely as the latter increases.

Hardness

The Brinell hardness of high duty and alloy cast iron varies from 140 to 450. The lower hardness is obtained from the cast irons having an austenitic structure as a result of alloy additions and the higher hardness from irons with a martensitic structure produced by alloy additions and subsequent heat-treatment. Pearlitic cast irons usually have a Brinell hardness varying from 160 to 250, and in these irons the hardness in general increases as the strength increases. Experience has shown, however, that there is no definite relationship between strength and hardness as in steel, and also that there is no relationship between hardness and machinability or hardness and wear. Austenitic cast irons with a low Brinell hardness are found to have much better wearing qualities than pearlitic irons with a higher hardness, and sorbitic cast irons produced by the hardening and tempering of alloy cast irons which have a Brinell hardness of 250 to 350 are found to machine fairly easily. In Tables III and IV Brinell hardnesses of typical high duty and alloy cast irons are given.

Shear Strength

In the American Society for Testing Materials investigation on impact testing, shear tests were made on all the cast irons experimented with. These tests, which were determined on cylinders 0.505 in. in dia. using a double shear apparatus, checked previous determined data and showed that the relationship of shear stress to tensile stress is similar to that of transverse rupture stress and compressive strength. Shear strength is found to be about 1 to 1.6 times the tensile strength, the narrower ratio applying to the higher strength irons and the wider ratio to the weaker irons. In Table IV are given some values for shear strength for high strength and alloy cast irons.

Torsion

With regard to the properties of cast iron in torsion, very few investigations have been carried out, and sufficient data are not available to judge the relationship of torsional strength to tensile strength. Some interesting results, however, which indicate torsional properties in high duty and alloy cast iron, are included in an investigation by Gough and Pollard[6] on the properties of some materials for cast crankshafts with special reference to combined stresses, and are given in Table VI.

Impact Strength

There is no standard test for the testing of cast iron for impact or shock resistance, although many empirical forms are in use. Cast iron is not commonly used for parts which have to resist impact or sudden shock, and this perhaps is the principal reason why more attention has not been paid to methods for determining this property. The advent of high duty and alloy cast irons, however, and of cast irons susceptible to heat-treatment has extended the use of cast iron to parts which are subjected to impact and vibratory stresses, and has therefore necessitated a more accurate knowledge of its shock-resisting properties.

As cast iron is a brittle material, the usual methods of determining impact resistance, which have been found satisfactory with ductile materials, and which have long been standardised for such alloys, are not adaptable. Standard Izod tests, on account of their small section and notch, give very low results, varying from 0.8 to 2 ft.-lbs., and small notched Charpy tests give somewhat similar results, varying from 0.5 to 3 ft.-lbs. With such tests it is impossible to differentiate between the impact resistance of different cast irons. More comparable results are obtained with large unnotched test-pieces using machines of the Izod and Charpy types, and with drop impact testing machines. The best results, however, are obtained with repeated blow tests, and this conclusion is arrived at from a systematic investigation on impact testing carried out by Sub-Committee A3 on Cast Iron of the American Society for Testing Materials.[5] In this research twenty-five cast irons, having a wide range of compositions and prepared by various melting methods, were submitted to thirteen types of impact tests. Tension, transverse, compression, hardness, fatigue and shear tests were also carried out. The results obtained from seven of the irons are given in Tables IV and V.

The repeated impact test can be made to approach either a single blow test on the one hand or a fatigue test on the other by varying the weight and height of fall in a Krupp-Stanton testing machine, and the repeated impact test

TABLE IV.—*Composition and Tests of Cast Irons (A.S.T.M. Tests).*

Test mark.	Composition.									Ultimate breaking stress.	Transverse rupture stress.	Deflection on 18-in. span.	Compression test.	Shear stress.	Brinell hardness.	Endurance limit.
	T.C	Si	Mn	S	P	Ni	Cr	Cu	Mo	Tons per sq. in.	Tons per sq. in.	In.	Tons per sq. in.	Tons per sq. in.	—	Tons per sq. in.
A ..	3.49	1.68	0.54	0.074	0.74	—	0.01	—	—	13.1	29.1	0.284	49.9	17.9	183	6.6
J ..	2.61	2.38	0.77	0.015	0.06	1.08	0.09	—	—	22.5	41.6	0.272	70.0	27.2	269	10.8
L ..	3.05	2.70	0.79	0.089	0.16	0.6	0.24	—	0.45	17.5	36.5	0.301	58.5	19.9	228	8.1
S ..	3.38	1.18	0.82	0.078	0.14	0.95	0.01	—	—	13.7	29.0	0.267	50.0	18.3	192	7.2
V ..	2.50	2.20	0.74	0.088	0.04	—	0.08	0.12	—	21.1	41.1	0.230	70.9	27.2	270	11.2
X ..	3.08	2.07	1.21	0.047	0.04	16.29	1.89	6.12	—	7.5	23.3	0.745	38.4	15.1	117	4.7
Z ..	2.79	2.44	0.50	0.060	0.03	0.50	0.09	0.36	—	25.3	49.8	0.490	60.6	25.5	231	11.2

TABLE V.—*Average Impact Tests (A.S.T.M. Tests).*

Test mark.	Pendulum tests, 1.2-in. dia. bar. Ft.-lbs.			Drop test, 1.2-in. dia. bar. Average drop-inch.				Izod test. Ft.-lbs.		Charpy test. Ft.-lbs.		Krupp-Stanton repeated blow.	Tensile impact. Ft.-lbs.
	Charpy, 18-in. span.	Russell, 18-in. span.	Russell, 8-in. span.	25-lb. hammer, 6-in. span, 2-in. first drop, 2-in. increment.	11-lb. hammer, 5-in. span, 1-in. first drop, 1-in. increment.	25-lb. hammer, 6-in. span, 1-in. first drop, 1-in. increment.	25-lb. hammer, 5-in. span, 2-in. first drop, 2-in. increment.	Small specimen unnotched.	Small specimen notched.	Small specimen notched.	Small specimen unnotched.		
A ..	47.3	551	351	10.5	20.0	17.3	11.5	3.68	0.9	0.83	2.9	3,424	7.2
J ..	67.0	966	511	15.2	31.0	23.3	18.0	5.69	1.5	1.00	3.0	8,921	11.7
L ..	67.4	806	487	13.5	31.3	22.3	16.0	5.06	1.6	0.83	3.1	2,933	11.5
S ..	61.7	602	440	10.8	25.0	18.0	11.5	5.15	1.6	1.00	3.2	5,347	8.9
V ..	55.1	580	391	13.2	30.3	20.3	13.0	4.42	1.8	0.92	2.7	6,461	12.0
X ..	128.7	1,120	1,054	12.3	28.0	24.0	16.0	9.5	1.9	—	3.6	—	7.7
Z ..	138.8	1,632	935	21.4	47.0	28.0	24.0	8.16	1.7	3.0	4.1	19,235	19.7

developed and used by the British Cast Iron Research Association[7] is constructed to avoid both these extremes, and consists essentially of a hammer or tup dropping from a given height and operated by means of a cam so as to deliver a striking blow of 0.48 ft.-lbs. on a cylindrical test-piece, 15 mm. in dia., having a shallow round notch. As results obtained by this test take a considerable time to determine on some irons, another test, a single blow test, has been developed by the Association using the standard Izod machine, with a special vice, and a 0.798-in. unnotched, round test-bar. Results obtained by those two tests on high duty and alloy cast irons are given in Table III.

It will be seen from the values obtained for the repeated impact tests that there is a wide range in such tests, from 650 for a good cylinder iron to over 100,000 for a high duty iron and that more uniform results are obtained than from the single blow tests. There is little direct relationship between the impact strength and the tensile strength, a pearlitic iron with a good tensile strength having a low impact value and an austenitic iron with a low tensile strength a much higher impact value. It has been suggested that the impact strength of cast iron depends on its ability to deform plasticly under load, and as the plastic property is constant at about 25 per cent. of the total deformation at fracture, the impact value of cast iron will increase with the strength, provided the plastic value does not vary from normal. In austenitic cast irons, where the plastic property is high, a high resistance to shock is obtained and in high strength irons of poor plastic properties low impact values result.

Fatigue Strength

Many engineering structures in which cast irons are used are subjected to fluctuating or reversed stresses or to vibration, and if failure occurs it is usually associated with fatigue of the material, so that a knowledge of the endurance properties of cast iron is therefore necessary. In the past cast iron has been used chiefly under static conditions and its wider application for rotating and other moving parts of machinery involving rapid and continuous reversals of stress is of more recent date, so that investigations on the fatigue properties of cast iron have only been undertaken during comparatively recent years.

The principal researches on the fatigue of cast iron have been carried out in the United States, Germany, and more recently in Britain at the National Physical Laboratory. In America systematic investigations have been the work of Moore, Lyon, and Inglis[8]; Kommers,[9 10] and the Sub-Committee A3 on Cast Iron of the American Society for Testing Materials[5]; in Germany the work of Thum and Ude[11] and of Pfannenschmidt[12]; and in Britain of Gough and Pollard.[6] Most of the investigations have been devoted to measuring the endurance limit under simple stress systems, such as direct flexural or torsional stresses, except in the case of the work of Gough and Pollard, where data are also obtained for the behaviour of cast iron under combined fatigue stresses.

The data which have been acquired from those investigations show that cast iron has a relatively higher fatigue strength in relation to its tensile strength, when compared with other metals and alloys, an endurance ratio of 0.45 to 0.6 being obtained. The fatigue strength of high-duty and alloy cast irons is not increased except in so far as the ultimate tensile strength is increased, an equally high endurance ratio being obtained with lower grade irons. The ratio of fatigue strength to compressive strength varies between 0.13 and 0.15 and the ratio of fatigue strength to transverse rupture stress approximates to 0.26.

The influence of surface finish, as shown with ground or polished test-bars, on fatigue strength is small, there being only a very slight increase in strength if any. The effect of grooving or notching in decreasing the fatigue strength of cast iron is very much less than that obtained for most other metals and alloys and also less than theoretical calculation would indicate. This is assumed to be due to the heterogeneous nature of cast iron and to the fact that graphite plates may be looked upon as a series of small notches, and that one more artificial notch or scratch has little further effect. High-duty irons therefore show the effect of notching to a much greater extent than do medium or low-grade irons due to their finer graphite distribution. Understressing cast iron for a considerable period increases the fatigue strength to a greater extent than similar understressing on steel.

In Table VI are given the static test, fatigue strength, torsional fatigue stress, and fatigue strengths under combined stresses for four high-duty and alloy cast irons, as determined by Gough and Pollard. The copper-chromium cast iron is a heat-treated cast iron containing: C, 1.56; Si, 1.16; Mn, 0.44; S, 0.049; P, 0.067; Cr, 0.46; and Cu, 1.75 per cent. The inoculated iron contains: C, 2.75; Si, 1.59; Mn, 0.88; S, 0.073; P, 0.076; and Mo, 0.29 per cent. The chrome-molybdenum iron contains: C, 3.28; Si, 2.19; Mn, 0.95; S, 0.095; P, 0.17; Cr, 0.42; and Mo, 0.95 per cent. The nickel-chromium iron contains: C, 3.36; Si, 1.22; Mn, 0.92; S, 0.113; P, 0.124; Ni, 1.87; and Cr, 0.47 per cent.

The last three of the irons mentioned are tested in their as-cast conditions. All four irons are commercial cast irons and are being increasingly used for many engineering parts, and the inoculated iron is stated to be specially developed for cast crankshafts, which are parts particularly subjected to combined fatigue stresses. Fatigue strengths for high-duty and alloy cast irons are also given in Table IV.

Thermal Conductivity

The thermal conductivity of grey cast iron has been determined by a number of investigators including the author,[13 14 15] and consideration of the results obtained shows that the conductivity varies from 0.100 to 0.137 cal. per cm. sec. according to the composition and structure of the material, and that in most irons it has a negative temperature co-efficient. Definite values have been obtained for the thermal conductivities of ferrite, pearlite, and cementite of 0.187, 0.124, and 0.017 respectively. The influence of silicon is most marked, the conductivity decreasing rapidly with increase in the silicon content. With over 2 per cent. of silicon the falling-off in conductivity is reduced considerably owing to the formation of a ferrite structure. Phosphorus tends to produce a slight decrease in thermal conductivity and manganese has a somewhat similar influence. Heat-treatment at temperatures up to 550 deg. C. at first increases the thermal conductivity due to pearlite decomposing to form pearlite and graphite, after which oxidation of iron in the vicinity of the graphite flakes causes a slight decrease.

TABLE VI.—*Summary of Static, Impact, Hardness, and Fatigue Tests on High Duty and Alloy Cast Irons (Gough and Pollard.)*

Material.			Copper-chromium iron.	Inoculated iron.	Chrome-molybdenum iron.	Nickel-chromium iron.
Tensile limit of proportionality, tons per sq. in.			15.5	2.5	2.5	2.2
Ultimate tensile strength, tons per sq. in.			32.3	23.3	20.8	18.8
Modulus of elasticity, lbs. per sq. in. × 10^{-6}			26.8	21.7	20.1	18.7
Brinell hardness			260.0	245.0	280.0	265.0
Torsional limit of proportionality, tons per sq. in.			15.6	4.3	2.7	2.7
Torsional modulus of rupture, tons per sq. in.			38.6	31.9	32.7	21.1
Total twist at fracture (L/D = 8½), degrees			96.0	82.0	53.0	16.0
Modulus of rigidity, lbs. per sq. in. × 10^{-6}			11.4	8.6	8.6	7.1
Izod, notch bar, ft.-lbs.			1.2	1.5	0.8	0.4
Wohler fatigue limit, tons per sq. in.			± 21 to ± 19	± 12.9	± 9.4	± 8.9
Alternating torsional fatigue limit, tons per sq. in.			± 14.7 to ± 13.9	± 9.7	± 8.4	± 7.1
Fatigue resistance as determined using combined stress machine	Cycles of reversed bending stresses	Fatigue limit, tons per sq. in.	± 18.2	± 12.9	± 10.8	± 10.6
		Endurance ratio	0.564	0.554	0.519	0.564
	Cycles of reversed shearing stresses	Fatigue limit, tons per sq. in.	± 14.4	± 11.4	± 10.9	± 8.9
		Endurance ratio	0.446	0.489	0.524	0.473

TABLE VII.—*Thermal Conductivities of High Duty and Alloy Cast Irons (Donaldson).*

Type of cast iron.	Composition.									Ultimate breaking stress.	Thermal conductivity. Cal. per cm. per sec.	
	T.C	Si	Mn	Ni	Cr	Mo	Cu	Al	W	Tons per sq. in.	100 deg. C.	400 deg. C.
Hot mould	3.35	0.65	0.85	—	—	—	—	—	—	18.3	0.135	0.114
Chromium	3.17	1.40	0.97	—	0.392	—	—	—	—	18.4	0.131	0.115
Nickel	3.16	1.56	0.94	0.746	—	—	—	—	—	16.8	0.108	0.101
Tungsten	3.02	1.89	0.76	—	—	—	—	—	0.475	17.6	0.118	0.105
Plain	3.20	1.56	0.72	—	—	—	—	—	—	—	0.121	0.108
Copper	3.18	1.58	0.69	—	—	—	1.58	—	—	—	0.112	0.101
Plain	3.11	2.26	0.39	—	—	—	—	—	—	—	0.111	0.101
Chrome-molybdenum	3.12	2.31	0.39	—	0.54	0.77	—	—	—	—	0.119	0.109
Low carbon	2.61	2.46	0.45	—	—	—	—	—	—	22.7	0.110	0.100
Ni-tensyl	2.80	2.51	0.68	1.71	0.54	—	—	—	—	25.0	0.101	0.092
Manganese-nickel	3.10	2.51	3.11	1.00	—	—	—	—	—	24.7	0.106	0.097
Molybdenum	2.56	2.20	0.63	—	—	0.58	—	—	—	25.4	0.118	0.108
Nickel-chromium	3.41	1.03	0.65	1.49	0.54	—	—	—	—	21.5	0.116	0.106
Ni-resist	2.41	1.80	0.62	13.70	3.37	—	6.41	—	—	—	0.081	0.075
Aluminium-chromium	2.70	0.96	0.58	—	0.95	—	—	7.00	—	—	0.079	0.072
Nicrosilal	1.81	6.42	—	18.65	2.02	—	—	—	—	—	0.070	0.063

Thermal conductivity determinations carried out recently by the author[15] on high-duty and alloy cast irons deal with three series of cast irons over a range of temperature from 40 deg. to 530 deg. C. The first series of four irons consists of an unalloyed iron and of an iron of similar composition with an addition of 1.58 per cent. of copper, a second unalloyed iron and another of similar composition with 0.54 per cent. of chromium and 0.77 per cent. of molybdenum added. The irons in the second series are high-duty irons with tensile strengths of over 20 tons per sq. in. and include an unalloyed low-carbon iron, a molybdenum iron, an inoculated Ni-tensyl iron, a manganese-nickel iron and a nickel-chromium iron. The third series consists of the heat-resisting irons Ni-resist, Nicrosilal, and an aluminium-chromium iron. The results obtained from these irons together with the values previously determined from a hot-mould pearlitic iron, a nickel iron, a chromium iron and a tungsten iron, are summarised in Table VII.

The thermal conductivity values of the unalloyed irons range from 0.110 to 0.135 at 100 deg. C., according to their composition. The alloyed irons have conductivities ranging from 0.101 to 0.119 at 100 deg. C., and the heat-resisting irons conductivities ranging from 0.075 to 0.081 at the same temperature. The thermal conductivities of all the irons have negative temperature co-efficients.

The effect of copper and nickel is to lower the thermal conductivity of grey cast iron in a manner similar to silicon. The influence of copper in lowering the heat conducting property of cast iron appears to be less than half that of silicon, while the influence of nickel is probably about 30 per cent. more than that of silicon. Molybdenum tends to raise the thermal conductivity of grey cast iron, and in this respect acts in a similar manner to chromium and tungsten, although its influence is not so marked. Where nickel and chromium or nickel and manganese are alloyed together in cast iron, the influence of nickel in lowering the conductivity is counteracted to a slight extent by the chromium or manganese. A large proportion of nickel has a pronounced influence in lowering the conductivity, but where part of the nickel is replaced by copper the influence is not so marked. Aluminium, even in the presence of chromium, has a very pronounced influence in lowering the thermal conductivity of grey cast iron.

Electrical Resistivity

The electrical conductivity of cast iron in terms of its specific resistance or electrical resistivity has been determined by many investigators. Such investigations have been more or less confined to determining the influence of silicon and phosphorus on the resistivity, but the influence of special alloy additions has also been dealt with. The results of these researches have shown that the addition of silicon, nickel, manganese, or aluminium to grey cast iron produces a rise in the resistivity, cobalt causes it to decrease, copper increases the resistivity up to a maximum of 1 per cent. copper, after which it decreases, and chromium gives irregular results, but in general tends to produce a decrease. Values obtained for the electrical resistivity of grey cast iron show it to be between 60 and 100 microhms per cubic cm., while that of austenitic cast irons due to their high alloy content is about 150 microhms. It may be assumed, therefore, that the electrical resistivity of high duty and alloy cast irons depends largely on their composition and will lie between the above values.

Many investigations have been carried out with metals and alloys on their thermal and electrical conductivities to determine their relationship and to ascertain whether they behave according to the Wildemann-Franz-Lorentz law, $K.\lambda = T$ where K is the thermal conductivity, λ is the electrical resistivity, and T is a constant. Data obtained show that the law holds for pure metals, and also to a fair extent for steels, copper alloys, and aluminium alloys, but, due to the complex nature of cast iron, the relationship is difficult to establish. Some of the early investigations showed the possibility of a relationship between those properties, but the more recent work of Marechal and Listray[16] tends to show that the law does not apply to cast iron. If such a relationship could be established, it would be of great value for determining the heat conducting properties of cast iron at high temperatures. This has not been done so far, as thermal conductivity determinations are difficult above 600 deg. C., whereas electrical resistivity determinations are comparatively simple. If a definite relationship were established for these two properties in cast iron over a range of temperature up to 1,000 deg. C., it would allow thermal values at high temperatures to be calculated.

Thermal Expansion

The co-efficient of thermal expansion of cast iron has been determined over a range of temperature within fairly accurate limits, and shows variation with composition and structure. With pearlitic cast irons the variation with composition is slight and the co-efficient of expansion is approximately 1.4×10^{-5} over a range from 20 deg. to 650 deg. C., with an inflexion at a temperature between 200 deg. and 300 deg. C., the Curie point, where the co-efficient of expansion approximates to 1.1×10^{-5} Investigations by Norbury and Morgan[17] on irons of the Silal (6.0 per cent. silicon) and Nicrosilal (6.0 per cent. silicon, 18 per cent. nickel, 2 per cent. chromium) types have shown that, while the co-efficient of expansion of the former with a ferrite-fine graphite matrix is 1.4×10^{-5} the co-efficient of expansion of the latter with an austenitic matrix is about 1.8×10^{-5}. Systematic investigations by Sohnchen and Bornhofen[18] on this property have shown that the co-efficient of thermal expansion of cast iron tends to decrease linearly with increase in carbon content, with increase in nickel up to 1 per cent., with increase in copper up to 2 per cent., with increase in aluminium up to 8 per cent. and with increase in chromium up to 0.5 per cent. From the work which has been done, therefore, on this property, thermal expansion values for high duty and alloy irons can only be approximated to from a knowledge of their composition and structure.

Specific Heat

Many determinations have been made on the specific heat of pure metals and of steel and other alloys over a wide range of temperature, but there are very few data published on the specific heat of cast iron. The data which have been published show the specific heat of grey cast iron to be about 0.13 in the temperature range 20 deg. to 100 deg. C. and rising to 0.175 at 1,000 deg. C. So far no definite relationship has been established between the specific heat of cast iron and the composition and structure, so that information with regard to the specific heat of high strength and alloy cast irons cannot be estimated.

Magnetic Properties

Determinations of the magnetic properties of cast iron have been carried out by a number of investigators during recent years, and certain data are available with regard to the influence of carbon and other elements, including alloy additions to cast iron, on such properties as magnetic permeability, coercive force, hysteresis loss, magnetic induction, remanent magnetism and saturation. The form in which carbon is present greatly influences the magnetic properties, ferrite gives low hysteresis loss and high permeability, pearlite high hysteresis loss and low permeability, and high alloy additions, by producing an austenitic structure, a very low permeability. In general, the magnetic properties depend largely on the nature of the structure of the iron, so that the influence of composition and alloy additions is an indirect one depending on how the structure is affected. Grey iron with a pearlitic structure has a magnetic permeability of about 240, while that of austenitic irons is about 1.05.

Other Properties

Properties of cast iron such as resistance to corrosion, wear and heat, and machinability, which are not intrinsic properties, depend, with the exception of the last, on the conditions which the material has to withstand in service, and are largely related to composition and structure. Austenitic irons, such as Nicrosilal and Ni-resist, have a much better resistance to wear, corrosion, and heat than irons with a pearlitic structure, but are brittle and lack the strength of pearlitic irons. Pearlitic cast irons show the best wear resistance when they contain small well-distributed graphite, and when the phosphide eutectic is also well distributed. They have little resistance to corrosion, however, and in this respect are similar to carbon and low alloy steels. Special irons to resist chemical corrosion, in addition to the austenitic irons, are high silicon irons containing 15 per cent. silicon and irons containing 10 per cent. chromium. The latter iron has also a good heat resistance, a property which is still more fully developed with 30 per cent. chromium (Table III), giving a strong, tough, machinable iron. An iron containing aluminium and chromium has also been successfully developed recently for heat resistance.

Another property of cast iron which has been brought into prominence in recent years is its damping capacity or capacity for dissipating vibrational energy. This property, which is developed in materials showing a large amount of plastic deformation and having a low modulus of elasticity, both of which cast iron possesses, absorbs stresses developed under working conditions and which, if they become superimposed, prove dangerous. In this respect it renders cast iron suitable for the manufacture of cast crankshafts.

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A New Magnetic Alloy

A Paper read before the American Physical Society by E. A. Nesbit and G. A. Kelsall, of the Bell Telephone Laboratories, New York, disclosed the development of a new material for permanent magnets which can be forged and rolled. Tape, two thousandths of an inch thick and a twentieth of an inch wide, has been manufactured. Its composition is stated to be 6 to 16 per cent. vanadium, 30 to 52 per cent. iron and 36 to 62 per cent. cobalt. A heat-treatment is necessary to develop its magnetic properties. The alloy is to be known as "Vicalloy."

A Lost Art?

The Paper on the "Welding of Cast Iron," which Mr. L. Tibbenham, M.I.Mech.E., presented to the East Anglian Section of the Institute of British Foundrymen (see the JOURNAL for May 23 last, p. 377), has been reproduced in "The Iron Age," and as a result brought forth an interesting commentary from Mr. P. Hall (president, Hall Planetary Company, Philadelphia), which is appended:—

About 35 years ago there was a man above Trenton, N.J., who had a very small shop in which he welded cast iron without heating the piece to be welded and made the weld stronger than the surrounding iron. This man died with his secret. He would not even give it to his son. The writer talked with him in 1907 and asked him to give the secret to his son so that cast iron could be welded after he passed out of the picture.

At that time the writer was building very high-grade petrol engines for motor boats, and his first experience in getting this man to do welding for the firm was by having the water jackets welded. These water jackets were $\frac{5}{16}$ in. thick and had a hole blown out of them about 6 in. by 8 in. due to hydraulic pressure. This man straightened up the hole, making it exactly square, putting a bevel on the side of the hole and putting a cast-iron plate in the hole. He then welded the plate in the hole so beautifully that when the weld was ground off, there were no defects in the weld. To test the weld, hydraulic pressure was again put on the cylinder and this time it broke out the casting around the weld but the weld or near the weld did not break. The foundry then returned the cylinder to the welder and again he put in a much larger piece. In neither case was the cylinder heated. After this quite a few cylinders were sent to this man but no one could find out how he made the weld.

Since then the writer has broadcast all over the country to find out if anyone knew how to weld cast iron. About eight years ago he was told that there was a man in the Chevrolet Gear and Axle plant, Detroit, who could weld cast iron. When in Detroit the writer called on him and was told he could not weld cast iron and that no one could weld it properly as the structure of cast iron made it impossible to weld. The writer told him his experience but probably he did not believe it as he had been trying to weld cast iron for a great many years. Strange to say the enamelling on these engine cylinders was never even discoloured from the cylinder being slightly heated.

If this man's secret could be found to-day, it would save the manufacturers of the United States millions of dollars. The weld was stronger than the surrounding iron.

Application of External Chills in the Production of Steel Castings

(*Continued from page* 139.)

chilled. The casting is sound. The contact surface is 16.5 in., the chill area 15.0 sq. in.

Conclusions

From the results obtained in this study the following conclusions are reached:—

(1) Chill design is as important as size.

(2) Chills should never be designed so as to form re-entrant angles of sand at their sides or ends, except where it is desired to retard or control the chilling effect.

(3) Placing of chills is important, and requires study.

(4) Where chills are to be used on section junctions, it is desirable to have the radii at least one-third as great as the section thickness, but never more than one-half as great.

Some Jobbing Foundry Experiences—V

By "TRAMP"

Cast-iron cisterns, of which Fig. 1 is typical, are sometimes called for in jobbing shops, and their manufacture presents a few points of interest. Where moulding boxes are available and lifting facilities adequate, this type of job can be moulded in a two-part box by the turnover method and cast in the position shown, which is ideal from the point of view of having the bulk of the metal in the bottom and so decreasing the risk of having a faulty plate due to "cold shuts" or other defect impairing soundness. Often, however, boxes are not available and another method—in which the plate has to be cast up and thus avoid having to turn the mould—has to be adopted. For this process a shell pattern, a replica of the desired casting, is prepared with the top part or plate made loose to facilitate ramming the pod of sand forming the interior. A bed having been made in the foundry floor and levelled off, the pattern

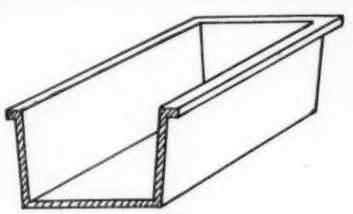


FIG 1

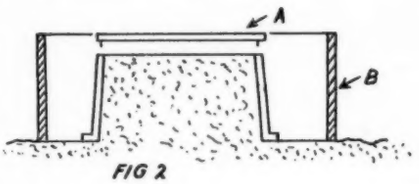


FIG 2

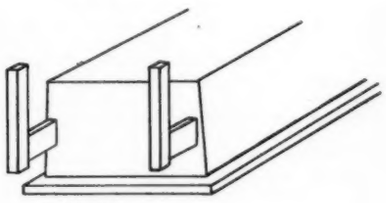


FIG 3

is placed in position as in Fig. 2, with the top part, A, removed.

The interior is now rammed, care being taken to vent and ensure that the top face is not too hard; otherwise trouble will be caused through "scabbing." Having rammed the interior, the top is placed on and a moulding box (B, Fig. 2) placed around the pattern. The outside is then rammed, the top lifted after being guided, and the pattern withdrawn. A runner penetrating into each side is prepared during ramming by the use of a draw in-gate, as shown in Fig. 3. Quite satisfactory castings are ensured by this method. A riser is placed at the far end of the plate and closed down during casting to avoid "drawing down" the top.

Electric Metal Spray Gun

A new method of metal spraying has been developed by Dr. M. U. Schoop, the Swiss physicist and chemist, who invented the autogenous welding of aluminium. The new invention is an electric spray gun that melts metal wires with the aid of a small luminous arc and sprays the metal on metallic and non-metallic surfaces by compressed air.

Properties of Commercial Pearlitic Malleable Iron

(*Continued from page* 136.)

malleables of the same hardness and composition have equal machining properties. The form of the carbide in the matrix, that is, whether it exists as spheroids or as lamellæ in pearlite, for example, must affect the machinability of pearlitic malleable just as these various forms of carbide affect the machinability of steel.

The microstructure of pearlitic malleable, particularly when isolated patches of ferrite are absent, suggests a material of high resistance to frictional and abrasive wear and galling. Performance in service of pearlitic malleable parts seems to bear this out. However, there is little concerning wear properties of pearlitic malleables in the literature.

Corrosion Resistance.—The corrosion resistance of copper-bearing Z-Metal in various solutions was shown[3] to be superior to that of standard malleable iron. Tests were made by suspending the specimens under no strain in the solutions held at 26 deg. C. Corrosion was expressed as the rate of loss of metal in milligrams per square centimetre of exposed surface over a fixed period of immersion. The results are summarised in Table I.

The results of such tests should only be accepted with reservation as they seldom are truly indicative of the behaviours of the materials in service. The character of the surface of the specimens, that is, whether it is machined or cast, is underlaid with a "picture-frame" structure, as may well be the case with standard malleable specimens, or is decarburised, also has an effect on rates of corrosion. The corrosion resistance of unalloyed pearlitic malleables can be increased by alloying.

Acknowledgment

The author wishes to express his thanks to the various producers of pearlitic malleable iron for information received that made this Paper possible, and to members of A.S.T.M. Committee A-7 on Malleable-Iron Castings for suggestions and encouragement received during its preparation.

The Electric Arc Furnace in Industry

(*Continued from page* 140.)

Operating Data

As to actual operating data of the rapid-type swing-aside-roof-lift furnace, the author states that in a plant having a furnace of 12-ton capacity, equipped with a 7,500-k.v.a. substation, the daily production was 198 gross tons of good ingots; the average unit power consumption ran 680 kw.-hrs. per gross ton of good basic ingots produced; the time cycle per heat from power on to power off was 2 hrs.; and the load factor on power usage, 64 per cent. The steel produced is of excellent quality, made from cheap bulky country scrap. The cost of the billet-size ingots is approximately £2 per ton less than the quoted market price from larger steelworks. While these results are being commercially obtained, they are still far from what is reasonably to be expected when all details of the plant operation have been perfected and systematised.

The author concludes that there is undoubtedly a very large and growing market for the electric-arc furnace not only in the steel and iron industries but also in the non-ferrous industry and in the smelting plants. The arc furnace market is not saturated and the power supply being made available indicates a large future increase in the growth of the electric-arc furnace industry.

The Week's News in Brief

Trade Talk

THE ANNUAL MEETING of the Institute of Metals is to be held at their headquarters on September 18, at 5 p.m.

THE INSTITUTION OF CHEMICAL ENGINEERS has decided to lend £2,000 to the Government free of interest for the duration of the war.

THE NORTH BRITISH LOCOMOTIVE Company, Limited, Springburn, Glasgow, have received an order for five duplicate locomotive boilers for Rhodesia.

BRITISH AND FRENCH GUNS on Tower Hill, outside the Tower of London, all of which are over 100 years old, are to be broken up for scrap. They will produce about 150 tons of metal.

FOR THE CONVENIENCE of customers in the southern area, Foundry Services, Limited, of Birmingham, have opened an office and store at 4, St. Clement Street, Islington, London, N.7. The telephone number is North 1448.

THE United States National Defence Advisory Committee has appointed a technologic committee on manganese, which will function under the National Academy of Sciences and the National Research Council. The chief purpose of the committee will be to consider new processes for recovery of manganese from low-grade domestic ores.

THE DIRECTORS of the Carron Company have given an ambulance wagon to St. Andrew's Ambulance Association to augment the war emergency fleet in Stirling and Clackmannan. Mr. George Pate, O.B.E., general manager, has asked that the wagon should be named "The Carron Ambulance."

THE MINISTRY OF ECONOMIC WARFARE announces that during July about 45,300 tons of contraband goods were seized by the British Control. Of this amount approximately 34,600 tons were taken off neutral ships and 10,700 tons off Italian vessels. Among the items in this total were 8,000 tons of phosphates and 6,800 tons of manganese ore.

MR. HERBERT MORRISON, Minister of Supply, speaking in London recently, said that within recent months steel supplies had begun to be swelled by very substantial purchases of finished material, made by the Ministry, from America. Mr. Morrison described as "fantastically untrue" the German statement that Britain was starved of raw material for steel.

SURVEYS OF THE iron-ore deposits in the province of Surigao in the Philippine Islands indicate that they are among the largest known orefields in the world. Operating costs are estimated to be reasonably low and adequate transport facilities, including a well-equipped harbour, are available for handling the ore. No decision has apparently been made regarding the exploitation of the deposits.

THE Ministry of Labour and National Service reminds employers and employees that under the Unemployment Insurance Act, 1940, on September 2 non-manual workers remunerated at a rate exceeding £250, but not exceeding £420 a year, become insurable against unemployment. Workers who will be brought into insurance should take steps to obtain unemployment books by that date from any convenient employment exchange.

THE Ministry of Labour announces the following new entries in the Schedule of Reserved Occupations:—Technical laboratory assistant (aero-engine production and developments, test observing and analysis), 18; research technical laboratory assistant (aero engines), 21; engineering and metal trades, including shipbuilding, sandblaster, sanding machine operator, sander, 30. These entries are not retrospective in effect, and therefore do not involve the release of men now in the Forces or of men who have already received enlistment notices.

THE speeding up of Canadian industry under the stimulus of war is producing a great demand for iron and steel. Total imports of iron and its products into Canada in the first quarter of the present year were valued at $55,195,000, as compared with $34,065,000 in the first quarter of 1939. Meanwhile imports from the United States rose from $29,509,000 to $50,148,000. Imports of rolling mill products increased in value, on the quarterly comparison, from $3,442,000 last year to $9,186,000 this year. The largest element in this group was sheets, plates, hoop, band and strip steel, but it included also structural iron and steel, and bars and rails.

MR. J. W. STEPHENSON, presiding at the annual conference of the Confederation of Shipbuilding and Engineering Unions at Southport last week, said it was amazing that there was any unemployment at all in the shipbuilding industry. There would be little substance in the shortage of skilled labour if the right methods were adopted to deal with any shortage that might temporarily arise. When skilled men were unemployed in a port, and in the same port employers were advertising for women to be trained for shipyard work, he said, the Confederation failed to see the sense or logic in such procedure. When they found the railways with redundant skilled craftsmen, and suggesting that they should accept jobs as porters at less wages, they were compelled to the conclusion that the best use was not being made of labour.

THE following awards have been made by the Council of the North-East Coast Institution of Engineers and Shipbuilders: Institution Scholarship (£100); Ian Welsh Goodlet, an apprentice of R. & W. Hawthorn, Leslie & Company, Limited, Newcastle-upon-Tyne. Bursary of £50: Eric William Simpson, an apprentice of A. Reyrolle & Company, Limited, Hebburn-on-Tyne. M. C. James Medal: Mr. H. J. Tapsell, of the National Physical Laboratory, for his Paper on "Creep at High Temperatures." Thomas Fenwick Reed Medal: Mr. Harry Chilton, now at sea, previously with the North-Eastern Marine Engineering Company (1938), Limited, Sunderland; awarded biennially in recognition of evidence of ability to take a share in the control of industry. R. L. Weighton Medal: Mr. Wilfred Bailey, awarded upon the result of the Durham Final Engineering Degree Examination at King's College, Newcastle-upon-Tyne.

Personal

MR. JOHN MCCONWAY has been appointed general manager of the Bede Metal & Chemical Company, Limited, and Mr. Charles McConway works manager.

MR. GEORGE BUCHANAN, M.P., of Glasgow, has been unanimously re-elected President of the Patternmakers' Association. This is Mr. Buchanan's fourth term as President.

PILOT-OFFICER H. L. NEWSOM DAVIS, formerly production manager of the Davis Gas Stove Company, Limited, Diamond Foundry, Luton, is a prisoner of war, it is officially announced.

MR. J. H. BODEN, after 25 years with the British Timken organisation in Birmingham, has retired owing to ill health. The occasion was marked by a presentation from the directors and staff.

MR. ERNEST HOLMES, of Leven, who has been appointed projects' engineer with Imperial Chemical Industries, Limited, at their Huddersfield Works, began his career as a draughtsman with Henry Balfour & Company, Limited, Durie Foundry, Leven. Recently he has been on the staff of I.C.I. at Glasgow.

Obituary

MR. ERNEST SMITH, a director of George Keighley, Limited, ironfounders and textile engineers, Burnley, has died at the age of 34.

THE AMERICAN PRESS announces the death of Mr. Dudley Willcox, treasurer and assistant general manager of the Ajax Electrothermic Corporation, Trenton, Pa. He was in Europe during the period 1911-12 as representative of the Tabor Manufacturing Company.

THE DEATH has occurred of Mr. G. B. Chance, a departmental director of E. J. & J. Pearson, Limited, firebrick and refractory manufacturers, of Stourbridge, at the age of 60. He was responsible for the management of the company's Delph Works for 28 years, up to the time of his death. His appointment as departmental director came in 1935.

MR. P. S. BROWN, who died at his residence, Linlathen, Broughty Ferry, Dundee, on Thursday last, at the age of 85, began his career as an apprentice clerk at the age of 13 and rose to be chairman of Brown & Tawse, Limited, iron and steel merchants, Dundee and London, and of the Caledon Shipbuilding and Engineering Company, Limited. He was a director of several other companies.

COL. A. J. BAILEY, C.B.E., T.D., who died recently at the age of 73, was governing director of Sir W. H. Bailey & Company, Limited, iron and brass founders, and pump and valve makers, of Albion Works, Salford. He had several inventions relating to valves for steam pumps, etc., to his credit, and in addition to membership of the Institute of Metals and the Institution of Mechanical Engineers was a member of Council of the British Non-Ferrous Metals Research Association. He had been prominently associated with the Territorial Army, principally with the Lancashire Fusiliers, and had been awarded the Territorial Decoration. He was one of Salford's senior magistrates.

New Companies

(From the Register compiled by Jordan & Sons, Limited, Company Registration Agents, 116 to 118, Chancery Lane, London, W.C.2.)

W. Westwood & Sons, Limited—Capital, £500. Ironfounders, etc. Directors: C. Westwood, 18, Scyssel Street, Cubitt Town, London, E.14; and W. C. C. Westwood.

G. A. Robinson (Stoke-on-Trent), Limited—Capital £5,000. Steelmakers and converters, etc. Director: G. A. Robinson, Pine Croft, Baldwins Gate, Newcastle, Staffs.

W. J. Thompson (Bucks), Limited, 26, Bedford Avenue, Trading Estate, Slough, Bucks—Capital, £1,500. Engineers, founders, etc. Directors: W. J. and F. R. Thompson.

Freedman & Hughes, Limited, 7, Henshaw Road, Small Heath, Birmingham—Capital, £500. General engineers, founders, manufacturers of jigs, press tools, etc. Director: A. L. Freedman.

Birnam Products, Limited—Capital, £50,000. Manufacturers of and dealers in wire and wire products, etc. Directors: H. Smith, Gamston House, Gamston, Retford; L. Farris, and A. Smith.

Reports and Dividends

Range Boilers, Limited—Interim dividend of 5 per cent.

W. Canning & Company, Limited—Interim dividend of 5 per cent.

Incandescent Heat Company, Limited—Net profit for 1939, after depreciation, income tax and N.D.C., £7,165; brought in, £5,766; written off patents account, £10,000; carried forward, £2,931.

Aeroplane & Motor Aluminium Castings, Limited—Net profit, after taxes, for the year to March 31, £18,607; brought in, £8,477; dividend of 15 per cent.; carried forward, £18,459.

Brightside Foundry & Engineering Company, Limited—Dividend of 15 per cent. and a cash bonus of 10 per cent., making a total distribution for the year to June 30 last of 25 per cent.

Hartley & Sugden, Limited—Net profit for the year ended June 30, £10,019; brought in, £2,436; preference dividend, £1,661; provision for taxes, £7,353; dividend of 5 per cent. on the ordinary shares, £2,550; carried forward, £892.

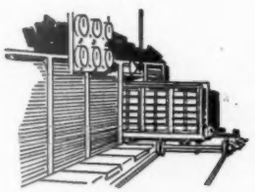
Davey Paxman & Company (Colchester), Limited—Profit to March 31, after depreciation, £29,639; debenture and other interest, £4,354; N.D.C., £260; E.P.T., £3,158; income-tax, £8,887; written off development account, £2,000; brought in, £11,919; dividend of 15 per cent.; carried forward, £8,531.

George Kent, Limited—Profit to March 31, £53,373; A.R.P. expenditure, £5,758; brought in, £41,391; depreciation, £10,378; tax, £6,240; debenture interest, £9,500; net profit, £20,312; debenture sinking fund, £2,345; final ordinary dividend of 6 per cent., making 9 per cent.; to staff funds, £3,500; carried forward, £40,812.

Richardsons, Westgarth & Company, Limited—Trading profit for the year ended March 31 last, after providing £31,444 for depreciation and setting aside £10,784 to debenture stock sinking fund, £103,982; brought in, £11,862; dividend of 7½ per cent., £26,427; carried forward, subject to income tax, £89,417.

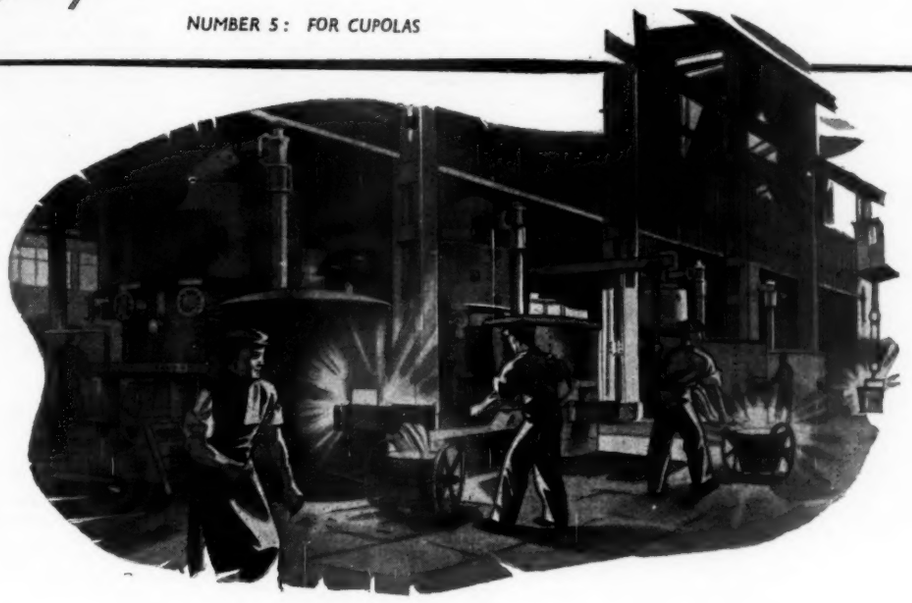
Metal Industries, Limited—Net profit for the year to March 31, £182,554; brought in, £82,197; income tax and N.D.C., £59,037; dividend on the 5 per cent. preference stock, £16,536; interim dividend on the "A" and "B" ordinary stocks of 2½ per cent., £35,497; to buildings and plant reserve, £6,351; to taxation reserve, £15,957; final dividend of 2½ per cent. on the "A" and "B" ordinary stocks, £31,578; carried forward, £98,245.

REFRACTORIES ON PARADE



YEARS OF RESEARCH HAVE RESULTED IN THE PRODUCTION OF FOUNDRY REFRACTORIES OF PROVED RELIABILITY

NUMBER 5: FOR CUPOLAS



A careful study of the exacting requirements necessitated by modern cupola operating conditions has resulted in the production of cupola refractories which will withstand the most severe conditions to be encountered.

The Technical Department will be pleased to advise on all problems relating to the application of cupola refractories and to make recommendations regarding the most suitable material for individual requirements.

Firebricks:
HYCONE
STOUR
WHITE CARR
GLENBOIG
etc., etc.

Daubing Materials:
HAZLEHEAD
GROUND
GANISTER.
GLENDOLINE
etc., etc.

Represent maximum output

always specify GENERAL REFRACTORIES PRODUCT

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Raw Material Markets

It is almost a year ago since the British iron and steel industry found itself called upon once again to play a vital part in the war effort of the nation, and it is gratifying at the conclusion of the first twelve months of the struggle to be able to report that the industry is now vastly better placed to meet the heavy requirements of the Government than it was at the outbreak of the conflict. That such a position has been attained must largely be attributed to the co-operative efforts of the producers and the Control authorities, who have from time to time during the past year been faced with many difficulties necessitating the most careful handling. Supplies of raw materials are arriving in the United Kingdom on a satisfactory scale, where these have to be imported, while our own resources are providing increased supplies, so that iron and steel makers may forge ahead to meet the many and varied calls of Government departments, in addition, at times, to a certain amount of export business and ordinary domestic home specifications, although these sections cannot yet be developed as would be desired.

Pig-Iron

MIDDLESBROUGH—Producers of Midlands foundry iron are able to meet the more urgent needs of Cleveland consumers, but there is little iron to spare for ordinary domestic users. Most foundrymen are now participaing in the war effort to some extent and, thus, only a few concerns are really badly situated for orders. Ironmasters here continue to operate their producing units almost solely on the manufacture of basic iron, and foundry iron output is still within very narrow compass. Makers' stocks of East Coast hematite are now very low, and the current output is fully accounted for by Government requirements. Despite an increase of production recently more iron would be easily disposed of, but better deliveries are expected to be made before long.

LANCASHIRE—The possibility of higher iron and steel prices being introduced after October 1 is very real in view of the threatened increase in railway freight rates, as it is unlikely that producers will be able to shoulder what amounts in their case to a considerable burden. Speciality engineers generally are well employed in this area, and the consumption of foundry iron for work of national importance is heavy. Users are, however, able to cover their immediate requirements, and full-scale operations are being recorded. The position of the light-castings branch still calls for improvement, but better returns are now being made, while most jobbing foundries are well situated. Textile-machinery makers as such are only moderately placed, but many of them have been able to divert their attention to work of greater urgency.

MIDLANDS—The supply of high-phosphorus iron is by no means free, but there is sufficient to meet the needs of Government users and the limited demands of the light-castings trade, which is usually considered to be the largest working-up industry. Foundries which are unable to take part in meeting the needs of the various supply departments, however, continue to be badly situated. Keen pressure continues to be exerted on low-phosphorus iron and hematite, both descriptions being fully accounted for. These grades are used in big tonnages by works busy on urgent orders, and there is little to spare for other purposes. However, by widespread changes in foundry practice, essential orders are being carried through, and the position is likely to improve rather than deteriorate.

SCOTLAND—While adequate supplies of pig-iron are available to cope with current demands, consumers are unable to purchase additional quantities to place into stock. Variable conditions continue to prevail in the light-castings trade, some makers having full order-books, whereas others cannot maintain full-time operations. Local steelworks are calling for heavy tonnages of both hematite and basic iron.

Coke

Good supplies of foundry coke continue to be available, and many consumers have taken full advantage of this position to rebuild their stocks. Coke ovens have been hit by the loss of a considerable proportion of their export trade, but the strength of the home demand has provided them with a good outlet. For delivery to Birmingham and Black Country stations, the price of Durham best coke remains at 55s. 6d. per ton, minimum, but this figure is subject to alteration by the Control authorities at any time.

Steel

While there is acute pressure in certain sections, the position of the steel industry is quite satisfactory in the circumstances. Where necessary home outputs have been supplemented by imports from the United States, and it is gratifying that the resources on the other side of the Atlantic have been made so freely available to us. Steelmakers, on the whole, are getting adequate supplies of raw materials, and outputs are not suffering on this account. There is a steady flow of Government orders to take the place of completed work, and little attention can yet be given to non-priority users. There has been some improvement in the export section, but only a limited tonnage of steel is available for shipment.

Scrap

Under the auspices of the Director of Scrap Supplies, Ministry of Supply (Iron and Steel Control), the first step has been taken in the work of scrapping disused factories and warehouses and reclaiming the metal for conversion into war materials. The first premises to be so treated are a boiler shop at Birkenhead, and the structural steel recoverable amounts to 125 tons. A considerable amount of metal is expected to result from this campaign. Deliveries of scrap to the consuming works have recently been vastly improved, and the shortage which has handicapped users in the past has disappeared, although considerable care is still being exercised in distribution in order to ensure a continuous flow of metal in the future.

Metals

Satisfactory conditions continue to be reported in copper, with priority users receiving plentiful supplies. Works dealing with export inquiries are also able to acquire quite good tonnages, and further expansion of the overseas trade is expected. A firmer tone has developed on the American market, and consumption is certain to grow as the defence programme gathers momentum. American producers generally report a quiet export demand, and the position is unsatisfactory. The attitude of the U.S. Government is to discourage further business with Japan and the Soviet Union, while the Empire resources of Britain leave little buying of virgin metal to be done with American concerns.

Tin consumers in the United States seem to be quite content to cover their immediate requirements, owing to the stocking policy adopted by the Government. The large users mostly have stocks on hand, but they are unwilling at present to draw on these extensively, preferring to buy on a hand-to-mouth basis.

In the House of Commons last week, Mr. R. R. Stokes asked the Colonial Secretary whether he accepted the total domestic tin assessments in Malaya as allocated by the Assessment Committee appointed by the Government of the Federated Malay States as representing the productive capacity of Malaya and, if so, whether he would give instructions to the Malayan Government to use those figures in future when considering standard tonnages. Mr. G. H. Hall (Colonial Under-Secretary), in a written reply, stated that the Colonial Secretary was advised that the assessments were the best estimate that could be formed locally as to the productive capacity of the territory, but they were, of course, merely estimates. The assessments were in continuous use for the purpose of translating into domestic quotas the international quotas fixed from time to time by the International Tin Committee.

The Malayan Chamber of Mines has pointed out to the Treasury that the present basis of assessing the 100 per cent. Excess Profits Tax will act as a direct deterrent to tin production in Malaya by companies registered in the United Kingdom, and asks for a modification of the method. Details of correspondence made available show that as far back as July 10 the Chamber submitted a memorandum to the Treasury stating the case for special treatment.

London Metal Exchange tin prices this week have been as follow:—

Cash—Thursday, £260 to £260 10s.; Friday, £260 5s. to £260 15s.; Monday, £260 to £260 5s.; Tuesday, £258 5s. to £258 10s.; Wednesday, £257 5s. to £257 10s.

Three Months—Thursday, £260 15s. to £261; Friday, £261 to £261 5s.; Monday, £260 10s. to £260 15s.; Tuesday, £258 15s. to £259; Wednesday, £258 to £258 5s.

After essential needs have been met the Control authorities are keen to place surplus supplies of spelter at the disposal of the export market, and ordinary domestic consumption is discouraged as far as is practicable. The foreign exchange acquired in this way is, of course, a useful asset, and all the metal that can be made available for shipment will be released. The lead position is very satisfactory. There is a considerable tonnage available after essential requirements have been satisfied, and, in addition to a fair amount of export trade, the more useful industrial inquiries are receiving attention.

Applications for Trade Marks

The following list of applications to register trade marks has been taken from the "Trade Marks Journal":—

"WYCHRO"—Iron having anti-abrasive properties. WYE FOUNDRY COMPANY, LIMITED, Stringes Lane, Willenhall, Staffs.

"CROMOL"—Iron and steel alloys. MIDLAND MOTOR CYLINDER COMPANY, LIMITED, Dartmouth Road, Smethwick, Staffs.

"ELMARID"—Common metals. TOOLS & DRAWING DIES, LIMITED, Shropshire House, 12-20, Pancras Street, London, W.C.1.

"INVICTA" (Device)—Goods included in Classes 7 and 11. Aveling-Barford, Limited, Invicta Works, Houghton Road, Grantham, Lincs.

"MAGNAFLUX"—Permanent magnets. WATSON, SAVILLE & COMPANY, LIMITED, Bruce Crucible Steelworks, Mowbray Street, Sheffield, 3.

"ALDAMELT"—Chemical preparations for welding, brazing and soldering. BRITISH OXYGEN COMPANY, LIMITED, Thames House, Millbank, London, S.W.1.

Contract Open

Cape Town, October 30—One 5-ton double girder, hand-operated, overhead travelling and traversing crane, complete with lifting and operating equipment and running rails and gantry girders, for the City of Cape Town Electricity Department. (D.O.T. reference: T. 21,342/40.)

Turkish Chromite

A recent decree issued by the Turkish Government placed at the disposal of the Eti Bank £T300,000 for handling the sale and export of all chrome ores produced in Turkey. The decree authorises the Eti Bank to give financial assistance to chrome producers by advancing funds against ores stored at ports of exportation. For chrome ores containing 48 per cent. Cr_2O_3, up to 80 per cent. of their value will be advanced on the basis of £T20 per ton. Chrome ores containing less than 48 per cent. Cr_2O_3 will be evaluated according to their content.

Ventilator Light Traps

The British Standards Institution, 28, Victoria Street, London, S.W.1, has issued a new specification B.S./A.R.P. 31 (price 8d., post free), entitled "Ventilation for Buildings in Conditions of Black-out." The specification has been prepared under the ægis of the Joint Lighting Committee of the Ministry of Home Security and the Illuminating Engineering Society. It describes the principles of design, the effect of light traps on ventilation, and suitable materials for the construction of ventilator light traps. Numerous illustrations of typical light traps suitable for various circumstances are then given.

ALUMINIUM ALLOYS
—to-day and to-morrow

In the unceasing development of Aluminium Alloys you can be sure that from our wealth of scientific experience, every help the foundryman can be given in perfecting casting technique, is given by International Alloys Ltd. Whenever there is a new specification for an Aluminium Alloy you can always rely upon this organisation as your best source of supply.

INTERNATIONAL ALLOYS LTD
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TELEGRAMS: INTALLOYD, SLOUGH ◆ TELEPHONE: SLOUGH 23212

RAW MATERIALS—PRICE LIST

Wednesday, August 28, 1940

COPPER*

	£	s.	d.
Electrolytic	62	0	0
High-grade fire-refined ..	61	10	0
Fire-refined of not less than 99.7 per cent.	61	0	0
Do., do., 99.2 per cent. ..	60	10	0
Black hot-rolled wire rods..	65	10	0

TIN

	£	s.	d.
Standard cash	257	5	0
Three months	258	0	0
Settlement	257	5	0
Official average Cash, July	265	15	2 1/23
Do. Three Months, July	265	9	4 3/23
Do. Settlement, July ..	265	14	6 1/23

SPELTER*

	£	s.	d.
G.O.B. (foreign) (duty paid)	25	15	0
Do. (domestic)	26	10	0
" Prime Western " ..	26	10	0
Refined and electrolytic ..	27	5	0
Not less than 99.99 per cent.	28	15	0

LEAD*

	£	s.	d.
Good soft pig lead (foreign) (duty paid)	25	0	0
Do., do., (Empire and domestic)	25	0	0
English	26	10	0
Sheets, home	34	10	0
Do. export, f.o.b. ..	30	0	0
Pipes, home	34	0	0
Do. export, f.o.b. ..	30	10	0
Tea lead (nom.)		—	

ALUMINIUM

Ingots	£110
Wire, 10g.	nom.
Sheets	nom.
Circles, 20/24g.	nom.

ZINC SHEETS, etc.

	£	s.	d.
Sheets, 10g. and thicker, ex works	39	2	6
Rolled zinc (boiler plates), ex works	37	2	6
Zinc oxide (Red Seal), d/d buyers' premises ..	28	7	6

ANTIMONY

English, 99%	90	0	0			
Foreign Regulus, duty paid ..	90	0	0	to	93	0	0
Chinese, prompt shipment, c.i.f. ..	79	0	0	to	82	0	0

QUICKSILVER

Quicksilver, ex-w'hse London 54 10 0

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	3s. 0d.
Finished bars, 18% tungsten	3s. 10d.
Finished bars, 22% tungsten	4s. 4d.

Per lb. d/d buyers' works.

NICKEL SILVER, etc.

	Per lb.
Ingots for raising ..	9d. to 1/3
Rolled—	
To 9 in. wide ..	1/3 to 1/9
To 12 in. wide ..	1/3½ to 1/9½
To 15 in. wide ..	1/3½ to 1/9½
To 18 in. wide ..	1/4 to 1/10
To 21 in. wide ..	1/4½ to 1/10½
To 25 in. wide ..	1/5 to 1/11
Ingots for spoons and forks	9d. to 1/5½
Ingots rolled to spoon size	1/- to 1/8½
Wire round—	
to 10g.	1/6½ to 2/1½

with extras according to gauge.

Special 5ths quality turning rods in straight lengths, 1/5½ upwards.

Maximum prices per long ton delivered to buyers' premises.

FERRO-ALLOYS AND STEEL-MAKING METALS

(all prices nominal)

	£	s.	d.
Ferro-silicon—			
25%	18	10	0
45/50%	21	10	0
75%	31	0	0
Ferro-vanadium—			
35/50%	15/6 lb. Va.		
Ferro-molybdenum—			
70/75% carbon-free ..	6/- lb. Mo.		
Ferro-titanium—			
20/25% carbon-free ..	1/9 lb.		
Ferro-tungsten—			
80/85%	5/1 lb.		
Tungsten metal powder—			
98/99%	5/2½ lb.		
Ferro-chrome—			
2/4% car.	—		
4/6% car.	47	0	0
6/8% car.	47	0	0
8/10% car.	—		
Ferro-chrome—			
Max. 2% car.	—		
Max. 1% car.	—		
Max. 0.5% car. ..	—		
70% carbon-free ..	—		
Nickel—99.5/100%	£190 to £195		
" F " nickel shot ..	175	0	0
Ferro-cobalt, 98/99% ..	8/9 lb.		
Metallic chromium—			
96/98%	3/9 lb.		
Ferro-manganese—			
76/80% loose	18	0	0
76/80% packed	19	10	0
Metallic manganese—			
94/96% carbon-free ..	1/9 lb.		

Per ton unless otherwise stated, basis 2-ton lots, d/d Sheffield works.

SCRAP*

	£	s.	d.		£	s.	d.
SOUTH WALES—							
Short heavy steel, not ex. 24-in. lengths.. ..	3	16	6	to	3	19	0
Heavy machinery cast iron			4	6	6		
Ordinary heavy cast iron			4	1	6		
Cast-iron railway chairs			4	6	6		
Medium cast iron ..			3	17	9		
Light cast iron			3	13	0		
MIDDLESBROUGH—							
Short heavy steel	3	14		3 to 3	16	9	
Heavy machinery cast iron			4	11	3		
Ordinary heavy cast iron			4	8	9		
Cast-iron railway chairs			4	8	9		
Medium cast iron ..			3	19	0		
Light cast iron			3	14	0		
BIRMINGHAM DISTRICT—							
Short heavy steel	3	9		3 to 3	11	9	
Hematite ingot mould			5	10	9		
Heavy machinery cast iron			4	11	9		
Ordinary heavy cast iron			4	7	0		
Cast-iron railway chairs			4	7	0		
Medium cast iron ..			3	19	9		
Light cast iron			3	14	9		
SCOTLAND—							
Short heavy steel	3	14		0 to 3	16	6	
Heavy machinery cast iron			4	13	9		
Ordinary heavy cast iron			4	8	9		
Cast-iron railway chairs			4	13	9		
Medium cast iron ..			3	16	9		
Light cast iron			3	11	9		

* Delivered free to consumers' works in England and Wales. For deliveries of cast-iron scrap free to consumers' works in Scotland, the above prices less 3s. per ton, but plus actual cost of transport or 6s. per ton, whichever is the less. All prices: Plus 2½ per cent. dealers' remuneration: 50 tons and upwards over three months 2s. 6d. extra

PIG-IRON*

	£	s.	d.
N.E. COAST (d/d Tees-side area)—			
Foundry No. 1	123/-		
" No. 3	120/-		
" No. 4	119/-		
Forge No. 4	119/-		
Hematite No. 1	131/-		
Hematite M/Nos.	130/6		
N.W. COAST—			
Hem. M/Nos. d/d Glas. ..	131/-		
" d/d Birm.	142/6		
MIDLANDS (d/d Birmingham dist.)—			
Staffs No. 4 forge	121/-		
" No. 3 fdry.	122/-		
Northants forge	118/6		
" fdry. No. 3 ..	119/6		
" fdry. No. 1 ..	122/6		
Derbyshire forge	121/-		
" fdry. No. 3 .	122/-		
" fdry. No. 1 ..	125/-		
Phosphorus 0.5% to 0.75%	129/6		
Phosphorus 0.1% to 0.5%	132/6		
SCOTLAND—			
Foundry No. 1, Grangemouth	119/9		
" No. 3, Grangemouth	117/3		
Cleveland No. 3, Glasgow	123/-		
" " Falkirk ..	120/-		
Scottish hem. M/Nos. d/d..	131/-		
SHEFFIELD (d/d district)—			
Derby forge	118/6		
" fdry. No. 3 ..	119/6		
Lincs forge	118/6		
" fdry. No. 3 ..	119/6		
W.C. hematite	136/6		
LANCASHIRE (d/d eq. Man.)—			
Derby fdry. No. 3 ..	125/-		
Staffs fdry. No. 3	125/-		
Northants fdry. No. 3 ..	123/6		
Cleveland fdry. No. 3 ..	125/-		
Cylinder and Refined Irons			
North Zone..	168/-		
South Zone..	170/6		
Refined Malleable			
Birmingham and S. Staffs ..	165/6		
Cold Blast			
South Staffs	217/-		

* Prices of hematite and basic pig-iron, and of foundry and forge iron with a phosphoric content of not less than 0.75 per cent., are subject to a rebate of 5s. per ton under certain conditions.

SEMI-FINISHED STEEL

Re-rolling Billets, Blooms and Slabs.

BASIC:	£	s.	d.
Soft, u.t., 100-ton lots ..	10	10	0
Tested, up to 0.25% C. ..	10	15	0
Tested, 0.25 to 0.33% C.	10	17	6
Tested, 0.33 to 0.41% C...	11	0	0
Hard (0.42 to 0.60% C.)..	11	17	6
" (0.61 to 0.85% C.)..	12	7	6
" (0.86 to 0.99% C.)..	12	17	6
" (1% C. and up) ..	13	7	6
Silico-manganese	14	5	0
Free-cutting	12	10	0
SIEMENS MARTIN ACID			
Up to 0.25% C.	13	15	0
Case-hardening	14	12	6
Silico-manganese	14	10	0

Billets, Blooms and Slabs for Forging and Stamping.

Basic soft, up to 0.25% C. ..	12	2	6
Basic hard, 0.41 to 0.60% C.	12	10	0
Acid, up to 0.25% C. ..	14	5	0

Other Semi-products, etc.

Tin bars	10	7	6
Sheet bars	10	7	6
*Wire rods, soft basic ..	15	4	0
" hard basic ..	18	12	6
" free-cutting ..	17	12	6
" acid	22	3	6

* Subject to rebate.

FINISHED STEEL

Usual district deliveries.

[A rebate of 15/- per ton for steel bars, sections plates joists and hoops is obtainable in the home trade under certain conditions.]

	£	s.	d.
Plates, ship (N.E. Coast) ..	14	3	0
Boiler plts. (N.E. Coast) ..	15	0	6
Chequer plts. (N.E. Coast)	15	13	0
Angles, over 4 un. ins. ..	13	13	0
Tees, over 4 un. ins. ..	14	13	0
Joists, 3 in. × 3 in. and up	13	13	0
Rounds and squares, 3 in. to 5½ in.	14	13	0
Rounds under 3 in. to ⅜ in. (untested)	15	8	6
Flats—over 5 in. wide ..	13	18	0
" 5 in. wide and under ..	15	8	6
Rails, heavy, f.o.t. ..	12	15	6
Hoops	16	3	6
Black sheets, 24 g. (4 t. lots)	19	7	6
Galv. cor. shts. (")	22	12	6
Galv. flat shts. (")	23	2	6
Galv. fencing wire, 8g. plain	24	7	6

FINISHED IRON

	£	s.	d.
CROWN IRON:			
England and Wales ..	15	2	6
Scotland	15	2	6
Ireland, f.o.q.	15	15	0
No. 3 BARS:			
England and Wales ..	12	5	0
Scotland	13	7	6
Ireland, f.o.q.	12	17	6
No. 4 BARS:			
England and Wales ..	12	15	0
Scotland	13	12	6
Ireland, f.o.q.	13	7	6
STRIP:			
England and Wales ..	16	10	0
STAFFS MARKED BARS, f.o.t...	18	0	0

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated August 6, 1940.

	Dols.
No. 2 foundry, Phila.	24.84
No. 2 foundry, Valley	23.00
No. 2 foundry, Birm.	19.38
Basic, Valley	22.50
Malleable, Valley..	23.00
Grey forge, Valley	22.50
Ferro-mang., seaboard	120.00
O.-h. rails, h'y, at mill	40.00
Billets	34.00
Sheet bars	34.00
Wire rods	2.00
	Cents.
Iron bars, Chicago	2.25
Steel bars	2.15
Tank, plates	2.10
Beams, etc.	2.10
Skelp, grooved steel	1.90
Steel strip	2.10
Steel sheets	2.10
Sheets, galv., No. 24	3.50
Wire nails	2.55
Plain wire	2.60
Tinplates, 100-lb. box	$5.00

COKE (at ovens)

Welsh foundry	42/6 to 44/-
" furnace	31/6 to 33/-
Durham foundry	30/6
" furnace	33/5
Scottish foundry	42/6 to 47/6
" furnace	31/6

TINPLATES

f.o.b. Bristol Channel ports

I.C. cokes	20 × 14 per box ..	28/-	
"	28 × 20 " ..	56/-	
"	20 × 10 "	39/6 to 40/6	
"	18¾ × 14 " ..	29/-	
C.W.	20 × 14 " ..	27/-	
"	28 × 20 " ..	55/-	
"	20 × 10 " ..	39/-	
"	18¾ × 14 " ..	28/-	

NON-FERROUS SCRAP

(Official Maximum Prices, per ton ex Works.)

	£	s.	d.
Bright untinned copper wire, in crucible form or in hanks	57	10	0
No. 1 copper wire	57	0	0
No. 2 copper wire	55	10	0
Copper firebox plates, cut up	57	10	0
Clear untinned copper, cut up	56	10	0
Braziery copper	53	10	0
Q.F. process and shell-case brass, 70/30 quality, free from primers	49	0	0
Clean fired 303 S.A. cartridge cases	47	0	0
70/30 turnings, clean and baled	43	0	0
Brass swarf, clean, free from iron and commercially dry	34	10	0
New brass rod ends, 60/40 quality	38	10	0
Hot stampings and fuse metal, 60/40 quality	38	10	0
Admiralty gunmetal, 88-10-2, containing not more than ½ per cent. lead or 3 per cent. zinc, or less than 9½ per cent. tin	72	0	0

NEW BRASS TUBES, etc.

	Per lb.
Solid drawn tubes	13½d.
Brazed tubes	15½d.
Rods, drawn	11½d.
Rods, extd. or rlld. ..	8½d.
Sheets to 10 w.g. ..	10½d.
Wire	10½d.
Rolled metal	9½d.
Yellow metal rods	8½d.

COPPER TUBES, etc.

Solid drawn tubes	14½d.
Brazed tubes	14½d.
Wire	9½d.

PHOSPHOR BRONZE

	Per lb. basis
Strip	13½d.
Sheet to 10 w.g.	13½d.
Wire	15½d.
Rods	15½d.
Tubes	20½d.
Castings	17d.

Delivery 3 cwt. free.

10% phos. cop. £35 above B.S.

15% phos. cop. £40 above B.S.

Phosphor tin (5%) £40 above price of English ingots.

C. CLIFFORD & SON, LIMITED.

AVERAGE MONTHLY PRICES OF DERBYSHIRE NO. 3 FOUNDRY AT MANCHESTER.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1904	2 17 6	2 17 6	2 11 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6
1905	2 13 0	2 13 0	2 11 6	2 12 6	2 12 0	2 12 0	2 12 3	2 12 3	2 14 0	2 16 6	3 0 0	3 0 6	2 14 1
1906	3 2 0	3 5 0	3 3 0	3 0 6	2 17 0	2 18 6	2 18 0	2 16 6	2 19 0	3 0 6	3 1 6	3 7 0	.. 0 8½
1907	3 7 0	3 7 0	3 5 0	3 2 0	3 4 0	3 8 0	3 6 0	3 5 0	3 4 0	3 2 6	3 1 0	2 18 6	3 4 2½
1908	2 15 0	2 14 6	2 15 6	2 14 0	2 13 0	2 13 0	2 13 0	2 11 6	2 12 6	2 13 0	2 12	2 12 6	2 13 5½
1909	2 13 0	2 12 6	2 11 6	2 12 0	2 12 6	2 12 6	2 12 0	2 12 6	2 14 6	2 15 0	2 14 6	2 14 0	2 13 9½
1910	2 13 9	2 14 0	2 14 0	2 14 4	2 15 0	2 15 0	2 14 9	2 15 0	2 15 0	2 15 0	2 15 0	2 15 0	2 14 7½
1911	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 14 6	2 15 0	2 15 0	2 15 8
1912	2 17 4½	2 17 6	2 17 6	3 1 1½	3 2 6	3 3 9	3 6 3	3 7 6	3 10 10½	3 12 6	3 13 3½	3 14 6	3 5 4
1913	3 15 7	3 15 0	3 11 10½	3 11 4½	3 10 2½	3 6 10½	3 4 2½	3 2 9	3 1 9	3 1 0	2 19 3	2 17 2½	3 6 5
1914	2 17 2½	2 18 0	2 18 0	2 17 0	2 17 0	2 16 7½	2 16 0	3 2 10	3 1 0	2 19 9½	2 16 11½	2 18 1½	2 18 2½
1915	3 1 2	3 3 11	3 5 9	3 18 8½	3 13 7	3 14 1	3 15 0	3 13 3	3 12 0½	3 11 1	3 14 0	4 3 3	3 12 2½
1916	4 4 6½	4 11 6	4 11 6½	4 7 6	4 7 6	4 7 6	4 10 0	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 8 6
1917	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6
1918	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6
1919	4 12 6	4 12 6	4 12 6	4 12 6	7 2 6	7 5 0	8 8 5	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	7 3 10½
1920	9 13 9	10 0 0	10 5 3	10 15 3	11 10 0	12 2 6	12 5 0	13 1 3	14 7 6	14 5 0	14 5 0	14 5 0	12 12 1
1921	12 11 8	10 8 9	9 2 6	8 2 0	8 0 0	8 0 0	8 0 0	8 1 8	7 4 0	6 7 6	5 7 6	4 1/ 10	8 0 2½
1922	5 5 0	4 17 6	4 15 0	4 15 0	4 12 6	4 12 6	4 12 6	4 12 6	4 11 3	4 10 0	4 10 0	4 10 0	4 13 7½
1923	4 12 8½	5 0 2	6 2 6	6 8 7½	6 2 5	5 11 9	5 9 1½	5 4 0	5 0 0	5 0 9	5 0 7	5 2 9	5 7 11½
1924	5 3 0	5 3 0	5 3 0	5 3 0	5 2 10	5 1 3	4 17 11	4 15 6	4 13 6	4 10 1½	4 10 0	4 10 3	4 17 9
1925	4 10 0	4 9 0	4 6 9	4 5 2½	4 3 0	4 0 1½	4 17 1½	3 15 7½	3 14 3½	3 13 4½	3 13 4½	3 13 2½	4 1 9
1926	3 14 9	3 15 3	3 15 6	3 15 3½	3 17 6	4 5 9	4 16 9	*	*	*	*	4 12 6	4 0 1½
1927	4 13 9½	4 13 3	4 11 1½	4 9 4½	4 6 1½	3 19 1½	3 16 1½	3 15 6	3 13 4½	3 13 4½	3 14 0	3 13 8½	4 1 6½
1928	3 13 2½	3 12 3½	3 12 3	3 12 3	3 11 6	3 10 0	3 8 3	3 7 8½	3 7 6	3 7 9½	3 8 3	3 7 6	3 9 10½
1929	3 8 3½	3 10 4½	3 10 10½	3 11 0	3 11 2½	3 12 0	3 12 4½	3 14 6	3 15 1½	3 17 0	3 17 0	3 17 0	3 13 1½
1930	3 17 0	3 17 0	3 17 0	3 17 0	3 17 0	3 17 0	3 15 0	3 12 0	3 12 0	3 12 0	3 10 1½	3 9 6	3 14 4½
1931	3 9 6	3 9 6	3 9 6	3 9 6	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 10
1932	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0
1933	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0
1934	3 7 0	3 9 6	3 13 2½	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 12 11½
1935	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 18 0	3 14 8
1936	3 18 0	3 18 0	3 18 0	3 18 0	3 18 0	3 18 0	4 3 0	4 3 0	4 3 0	4 3 0	4 3 0	4 9 0	4 1 0
1937	4 9 0	4 9 0	4 9 0	4 9 0	4 9 0	4 9 0	5 9 0	5 9 0	5 9 0	5 9 0	5 14 0	5 14 0	4 19 10
1938	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0
1939	5 4 0	5 4 0	5 4 0	5 4 0	5 4 0	5 4 0	5 4 0	5 4 0	5 4 0	5 4 0	5 13 0	5 13 0	5 5 6
1940	5 13 0	5 16 0	5 16 0	5 16 0	5 16 0	5 16 0	6 5 0	6 5 0	—	—	—	—	—

NOTE: Prices have been subject to a rebate of 5/- per ton since November 1, 1937. * No prices available during strike period.

WILLIAM JACKS & COMPANY
LIMITED
WINCHESTER HOUSE, OLD BROAD ST., LONDON, E.C.2.

CLARENCE CHAMBERS, 39, CORPORATION STREET, BIRMINGHAM.
13, RUMFORD STREET, LIVERPOOL.

PIG

IRON

All grades FOUNDRY, HEMATITE, BASIC, SPECIALS, &c.

NON-FERROUS METALS
COPPER, TIN, LEAD, SPELTER, ANTIMONY, CHROME ORE.

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Notice

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(A remittance should accompany instructions.)

SITUATIONS VACANT AND WANTED

ANALYST (Male or Female) with a knowledge of metallurgical analysis required by engineering firm in the North-West.—Applicants should give full details of training and experience, and state age and salary required, to BOX 436, Offices of THE FOUNDRY TRADE JOURNAL, 3, Amersham Road, High Wycombe.

INSPECTOR required by large jobbing Foundry in West Riding. Age 25 to 30. Experience in some of the following sections desirable:—

Pattern-making;
Core-making;
Moulding machine set up;
Fettling and spray painting.

Also able to take temporary charge of any Foundry section. Good salary and excellent prospects.—Box 438, Offices of THE FOUNDRY TRADE JOURNAL, 3, Amersham Road, High Wycombe.

REQUIRED immediately, an experienced man to take charge of production of Static and Centrifugally Cast Bearings for Aeroplane Engines. Good experience is essential, and successful applicants will be required to take charge of a Foundry attached to a new factory in the North.—Send full particulars of age, experience and salary required to Box A.E.F., CENTRAL NEWS, LTD., 5, New Bridge Street, London, E.C.4.

VACANCY for keen man with practical and commercial knowledge of foundry requirements, to supervise stores and maintain connection in the London area.—Box 442, Offices of THE FOUNDRY TRADE JOURNAL, 3, Amersham Road, High Wycombe.

EMPLOYMENT REGISTER.

Correspondence should be addressed to the General Secretary, Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester, from whom full particulars can be obtained of this service.

FOUNDRY MANAGER, specialist in High-Duty Cast Iron for small and medium Engineering Castings, accustomed to highly mechanised plant; also knowledge of modern core shop control, brass and light alloys, requires similar position. (390)

MANAGER or Assistant Foundry Manager desires re-engagement; Light Alloys to Air Ministry Specs.; Alloy Cast Iron; Grey Iron; green sand; dry sand. Jobbing and machine moulding; pattern shop. (391)

BUSINESS FOR SALE

FOR SALE.—Small Ironfoundry in North Midlands, specialising in Grey Iron Castings up to 10 cwts. Going concern. Owner retiring.—Box 440, Offices of THE FOUNDRY TRADE JOURNAL, 3, Amersham Road, High Wycombe.

PATENT

THE Proprietors of the Patent No. 333202 for improvements in or relating to pneumatic drop stamps are desirous of entering into arrangements by way of licence and otherwise on reasonable terms for the purpose of exploiting the same and ensuring its full development and practical working in this country.—All communications should be addressed in the first instance to HASELTINE LAKE & Co., 28, Southampton Buildings, Chancery Lane, London, W.C.2.

MACHINERY

WANTED, Cupola, one ton per hour.—Particulars and price to H. BREAKELL & Co., Pitt Street, Blackburn.

WANTED, Tilting or Rotary Furnace, 300-600 lbs. Brass capacity; coke, gas or oil fired.—WHYTE & EDWARD (METALS), LIMITED, Victoria Dock, Dundee, Angus.

FOR SALE.—One Incandescent Gas Furnace, with four burners, size of Oven, 1 ft. by 1 ft. by 2 ft. deep. Pyrometer by Elliott Bros. & Company, Limited; nearly new; £55.—ERICSSON BROS., LIMITED, 154, West Street, Erith, Kent.

SAND MIXERS AND AERATORS.—The "Breakir" Centrifugal Machine is *THE* machine. Outputs 10 cwts. to 8 tons per hr.—W. BREALEY & Co. LTD., Station Works, Ecclesfield, Sheffield.

CUPOLAS

6 ft. dia., 10 tons per hr.
3 ft. 6 in. dia., 3 tons per hr.
2 ft. 6 in. dia., 15-cwt. per hr. Cupolette.

PNEUMATIC MOULDING MACHINES

Macdonald Jolter, table 72 in. by 54 in.
Tabor 16-in. Shockless, table 72 in. by 48 in.
Tabor Portable Shockless Rollover, table 40 in. by 30 in.
Tabor ditto, table 27 in. by 20 in.
Tabor 21 in. by 16 in. squeeze.
Zimmerman Type R.P.W.2 Jolt Squeeze turnover, table 36 in. by 20 in.
Mumford Type (Jackman) Swing Headpress, 13 in. by 15 in. and 14 in. by 16 in.
Mumford Pneumatic Core Jolters having 15-in. by 20-in. and 12-in. by 12-in. tables.
Britannia No. 1 "Coventry" Pneumatic Turnover Jarr Ram, table 30 in. by 28 in.
Rotoil Oil Sand Mixer.
50 Air Compressors; 500 Electric Motors, Dynamos, etc.

S. C. BILSBY, A.M.I.C.E., A.M.I.E.E.
CROSSWELLS ROAD, LANGLEY,
Nr. Birmingham.
'Phone: Broadwell 1359.

THOS. W. WARD, LTD.

Tilghman belt-driven water-cooled Single-Cylinder AIR COMPRESSOR, 100 cub. ft. cap., 100-lbs. press. Auto unloader.

Broom & Wade V rope-driven Twin-Cylinder AIR COMPRESSOR, 80 cub. ft. cap., 100-lbs. press., 420 r.p.m. Auto unloader.

Ingersoll Rand Twin-Cylinder air-cooled AIR COMPRESSOR, 49 cub. ft. cap., 100-lbs. press. Auto unloader.

Write for "Albion" Catalogue

ALBION WORKS, SHEFFIELD
'Grams: "Forward." 'Phone: 26311 (15 lines).

PUBLICATION

RYLAND'S DIRECTORY of the Coal, Iron, Steel, Tinplate, Metal, Engineering, Hardware and Allied Trades. New edition. Price 42s. cloth bound, 52s. leather.—INDUSTRIAL NEWSPAPERS, LIMITED, 3, Amersham Road, High Wycombe.

MISCELLANEOUS

WORK wanted of National importance for Osborn Rollover Jolter Moulding Machine taking 30-in. by 30-in. boxes. Gunmetal or aluminium. Large weekly output guaranteed.—A.P.V., Northfield House, Wandsworth Park, London, S.W.18. Tel.: Putney 4492, Ex. 45.

LANCASHIRE Foundry wants to buy second-hand Top Part Moulding Box, approx. 9′ square × 8″ deep. In good condition. Urgent.—Box 432, Offices of THE FOUNDRY TRADE JOURNAL, 3, Amersham Road, High Wycombe.

"A STUDY IN ECONOMY"
ACTUAL MANUFACTURES
BY USING OUR

Foundry Blackings, Facings, Parting Powder, Core Gum, Terra Flake, Talc Coal Dusts, Ganister, Ceylon Plumbago (Imports direct). We definitely help to produce perfect Castings. Only the best minerals used in the making. A trial order will convince users of their economic value.

JOHN & C. DURRANS,
PENNINE WORKS, HAZLEHEAD,
NEAR SHEFFIELD.
Telephone: 128 Penistone
Telegrams: Facings, Penistone

'Phone: 22877 SLOUGH

TWO NEW Core blowers for bombs.

TWO NEW Shotblasts for bombs or shells.

NEW SANDMILL 4′ dia. £48.

CUPOLA'S. FOUR NEARLY NEW IN STOCK.

JOLT SQUEEZE "JACKMAN" MOULDING MACHINES, 14″ x 16″, as new. £90 each.

Morgan 250 lb. Tilting Furnace.

Monometer ½-ton Semi-rotary.

NEW PIT FURNACES 150 lbs. capacity, oil or coke fired. £35 each.

NEW SHOTBLAST CABINET PLANTS with motor driven Exhaust Fans, complete, all sizes. Prompt delivery.

ALEX. HAMMOND, *Foundry Machinery Merchants.*
14, AUSTRALIA ROAD, SLOUGH
BUY FROM ME AND SAVE MONEY.

WE SHOT OR SAND-BLAST FOR ALL TRADES

Airless and Pressure Blast Cleaning Plants

AIR COMPRESSORS
DUST ARRESTERS
CHILLED IRON SHOT—BLASTYTE
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